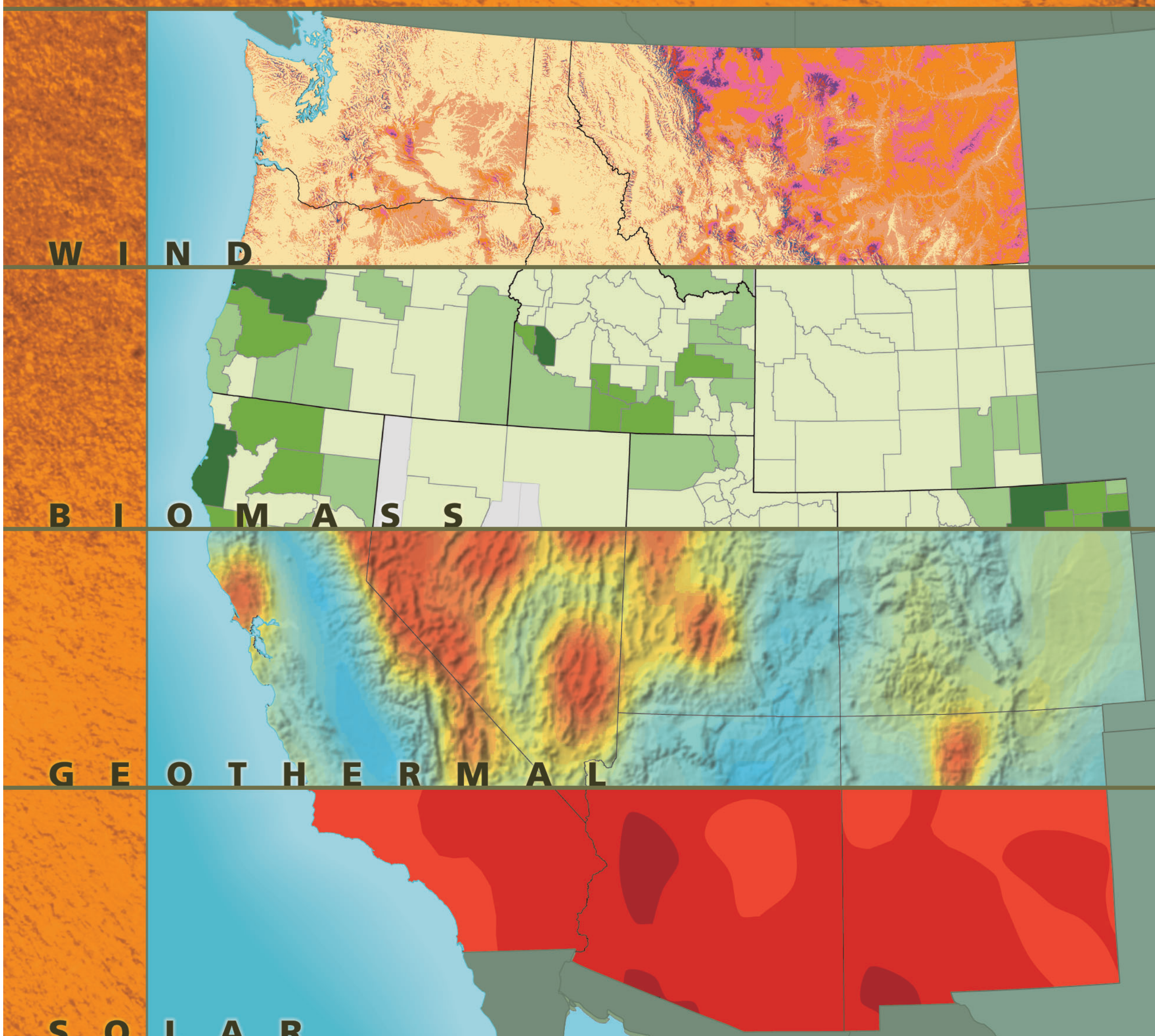
Renewable Energy Atlas of the West

A Guide to the Region's Resource Potential



A project of the Hewlett Foundation and The Energy Foundation
Produced and written by
Land and Water Fund of the Rockies
Northwest Sustainable Energy for Economic Development
GreenInfo Network

Part of the Hewlett Energy Series
www.EnergyAtlas.org

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Renewable Energy Atlas of the West: A Guide to the Region's Resource Potential

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Introduction

The Renewable Energy Atlas of the West is designed as a resource for policy makers, advocates, landowners, developers and others interested in furthering the production of electricity from renewable wind, solar, geothermal and biomass energy resources.

Purpose

Utilizing state-of-the-art GIS technology, the Atlas brings together the best existing renewable resource maps and data into a single comprehensive, publicly available document and interactive Web site. It does not provide a new regional assessment of renewable resources, but rather shows the current understanding of these resources throughout the West and highlights the issues affecting their development. In addition, it identifies areas where new data are needed in order to more accurately represent the region's renewable energy resources.

While the maps contained in this Atlas do not eliminate the need for on-site resource measurement, they can help developers gain a better understanding of where the best renewable resource areas are found and screen out the less promising areas. This can significantly minimize the cost and time involved in prospecting. Landowners can use the information for a first-cut feasibility analysis of using renewable resources to supply electrical power to their homes, farms, ranches and businesses, while policymakers will find it a useful tool for broader planning purposes.

Summary

The Atlas begins with an overview of regional maps of the wind, solar, biomass and geothermal resources. The second section describes the current status of renewable energy development, including a summary of the region's current electricity supply mix and a map of the locations and installed capacity of existing renewable energy facilities. A regional map shows state-level policies, including tax incentives, system benefits charges and portfolio standards, which have been implemented in several states to stimulate the development of renewable energy. The final section in the overview addresses important issues to consider in developing new renewable energy projects, including transmission capacity, load growth, land use and environmental impacts.

The Atlas continues with individual sections for each of the eleven Western states: Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington and Wyoming. Each state section features success stories of renewable energy development, state-level maps of wind, solar, biomass and geothermal resources and summaries of existing policies, installed renewable energy facilities and the current electricity supply mix. The final sections of the Atlas include a glossary, a technical notes section, and a list of resources for further information.

Why Renewable Energy Development is Important for the Region

The Western US is home to five of the ten fastest growing states in the country. This growth will greatly increase demand for electricity across the region over the next decade. Renewable resources can play an important role in helping to meet this demand. They provide clean, low-risk power that, over the long term, can lower the region's electricity costs.

Developing the region's vast renewable resources can provide:

Environmental Benefits	Economic Benefits	Security Benefits
▪ a cleaner environment ▪ better air quality ▪ improved public health ▪ reduced water usage for electricity generation	▪ economic opportunity ▪ rural economic development ▪ risk management ▪ fuel price stability ▪ lower costs over the long term	▪ energy independence ▪ system diversification and reliability

Future Research Needs

Several areas requiring further research, including basic resource assessments, refined power production potential estimates and data on transmission constraints, have been identified.

Fundamental assessments for wind, solar, biomass and geothermal resources are critical for planning purposes. New high-resolution wind power maps for Arizona, California, Colorado, New Mexico, Nevada and Utah are scheduled for completion by 2003. These new maps will more accurately portray windy lands in each state, and can provide important data of seasonal and diurnal patterns for comparison to load profiles and transmission availability. Efforts are also underway to map solar radiation data in greater detail, which can assist in evaluating solar potential in shaving peak demand. Geothermal resource estimates are particularly difficult, as test drilling is generally required to determine whether a location is suitable for power production. However, a better understanding of geothermal modeling techniques could assist planners. Finally, improved biomass resource estimates would be helpful, particularly for Nevada, and updates of available wood wastes and forest residues may be needed.

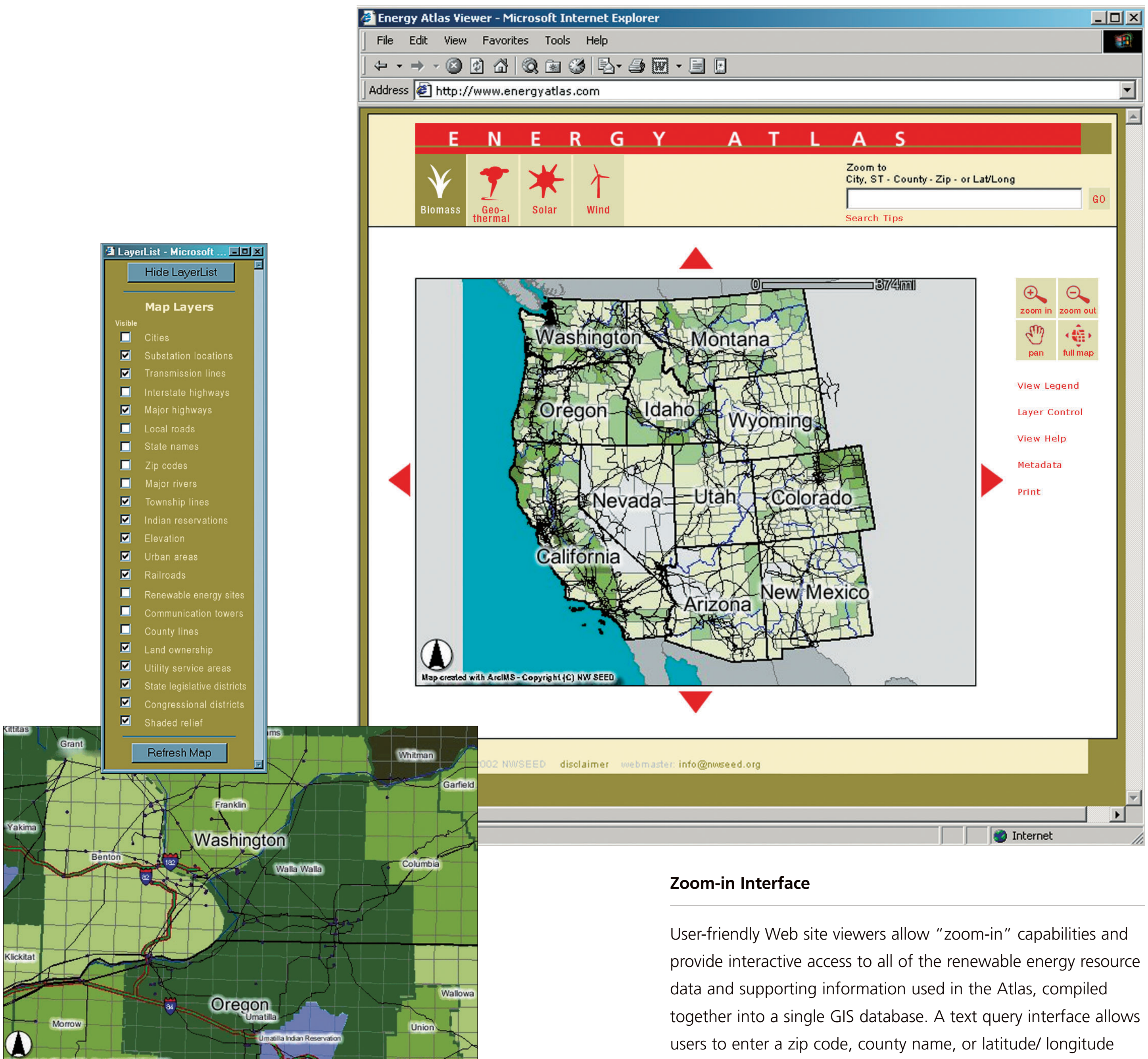
For solar, biomass and geothermal, power production estimates hinge on many unknown components, including future cost reductions and technology innovations that will make these resources more competitive.

Transmission constraints represent a significant barrier to large-scale renewable resource development, however renewables also stand to contribute greatly in the shift to increased reliance on distributed generation near loads. Information on the location and severity of transmission constraints and their relationship to geographic and temporal characteristics of the region's renewable resources will help in integrating these resources into the regional power grid.

EnergyAtlas.org

In addition to the printed version, the Atlas is available online. Interactive features include zoom-in selections and overlays such as boundaries for Native American reservations, state legislative and congressional districts, utility service territories, and links to related resources.

www.EnergyAtlas.org



Zoom-in Interface

User-friendly Web site viewers allow "zoom-in" capabilities and provide interactive access to all of the renewable energy resource data and supporting information used in the Atlas, compiled together into a single GIS database. A text query interface allows users to enter a zip code, county name, or latitude/ longitude value to zoom to a desired location; buttons allow easy toggles between resources and optional overlays.

The Renewable Resources

Wind

Wind power is the fastest growing energy resource in the world. Good wind areas, found on 6% of the land in the Western states, could supply more than five times the region's current electricity consumption. This emission-free resource is already being harnessed across the region, but at a fraction of its potential.

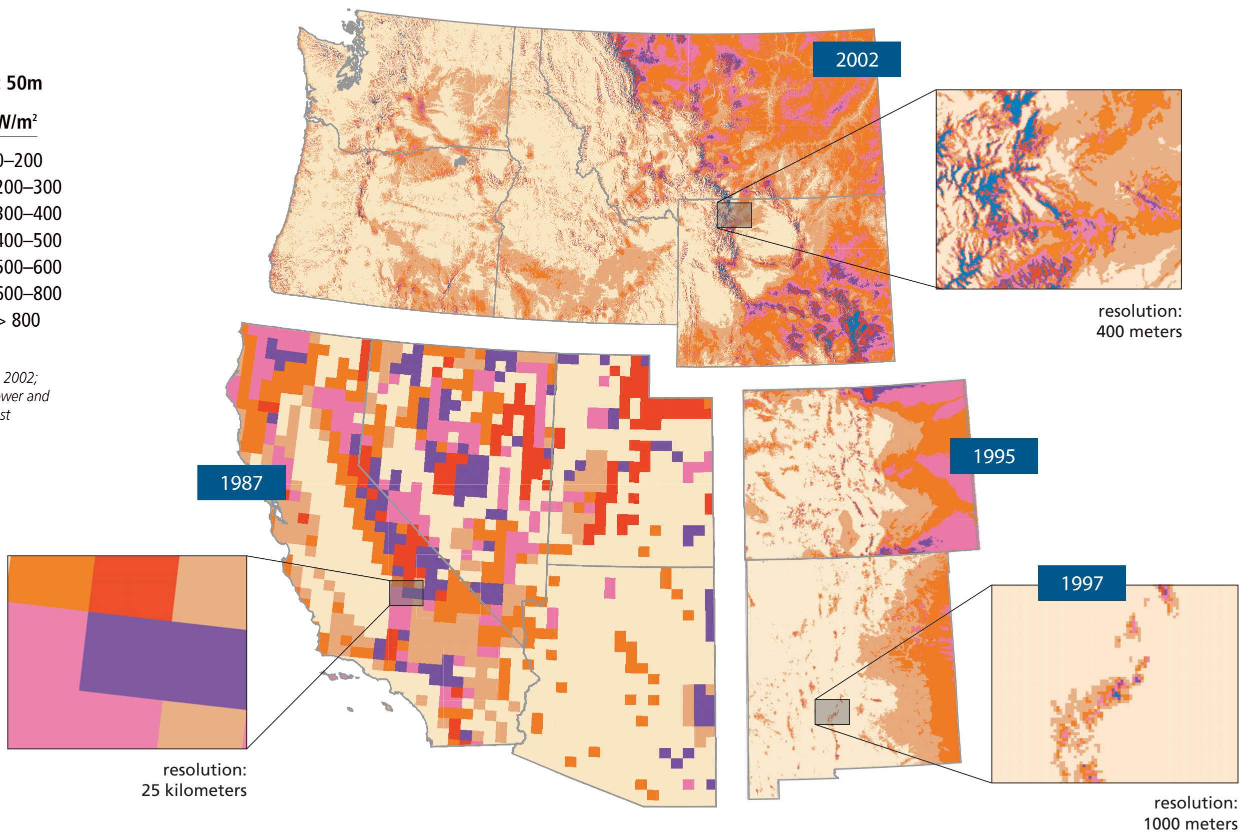
Wind resources adequate to power commercial wind farms are very site specific. Relatively small differences in the average wind speed have major impacts on energy production.

The energy potential in the wind is expressed by wind power classes ranging from 1 (least energetic) to 7 (most energetic). Each class is defined by a range of wind speeds and power densities, the expected watts per square meter of the blade swept area. Nearly 2,300 Megawatts of wind turbines are currently installed in the eleven Western states (according to the American Wind Energy Association).

Wind Power Density at 50m

Class	W/m²
1 Poor	0–200
2 Marginal	200–300
3 Fair	300–400
4 Good	400–500
5 Excellent	500–600
6 Outstanding	600–800
7 Superb	> 800

Data source: TrueWind/NWSEED 2002; Brower and Company 1997; Brower and Company 1995; Pacific Northwest Laboratory 1987



Wind Resource Maps: 1987 to 2002

Wind mapping techniques have improved significantly over the past 10 years. The 1987 Wind Energy Resource Atlas of the United States provided coarse approximations of wind resources. Although it was produced with the best methods available at the time, the 1987 atlas both underestimated and overstated wind resources for specific locations, as gridcell designations were only intended to represent well exposed areas. In the mid-1990s, updated techniques were used to produce maps for Colorado and New Mexico, increasing the resolution from 25 kilometers to 1 kilometer. Since 1997, wind mapping techniques have improved even further, and in 2002, updated maps were produced for Idaho, Montana, Oregon, Washington and Wyoming. The resolution is now 400 meters, a significant improvement over the old standard of 25 kilometers. The image above compares the most recent data for each of the eleven Western states.

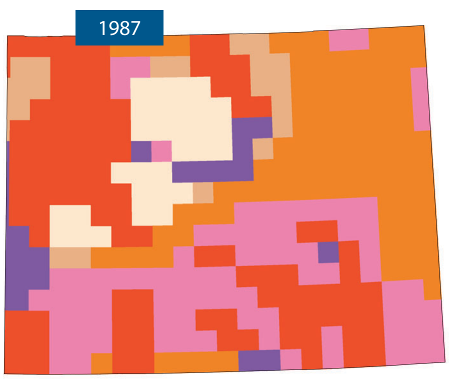
New Technology Provides Reliable Estimates of Windy Land Area

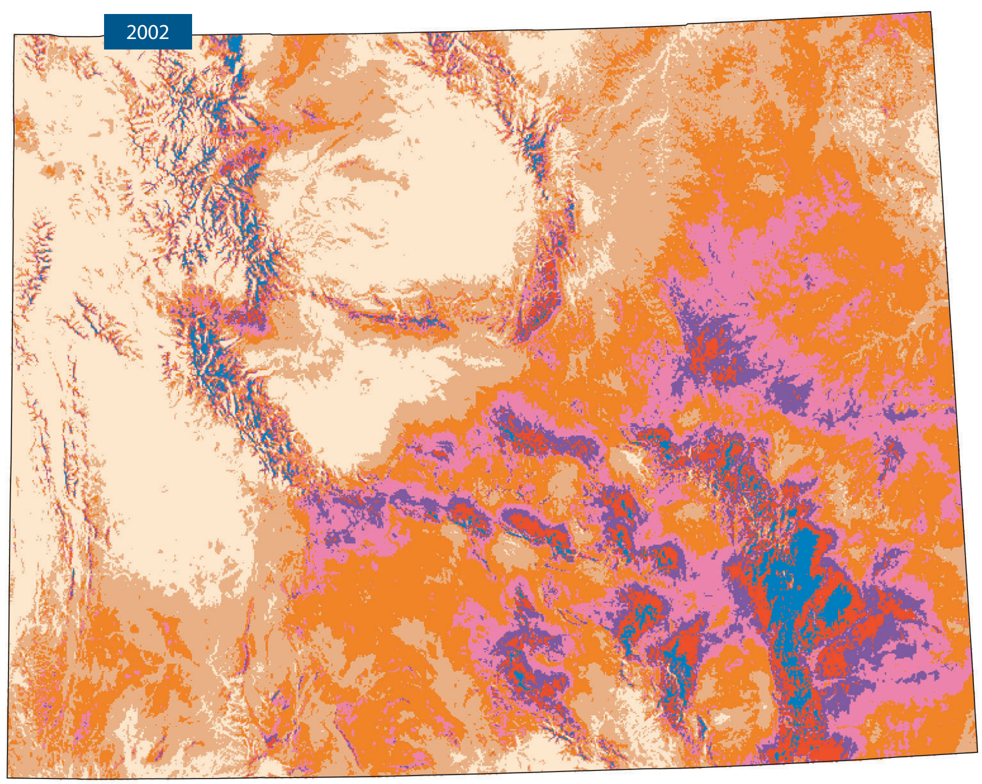
Improvements in wind resource mapping techniques can more accurately identify suitable areas for wind power development. This chart shows the estimated acreage of land suitable for commercial wind power development in each state. As wind resources in the rest of the Western states are mapped using the newest methods, clearer pictures of lands available for wind development will emerge.

Areas Available for Wind Development (Class 4 or Above)

State	1992 Pacific Northwest Laboratory Maps (acres)	2002 High-Resolution Data (acres)
Arizona	77,000	NA
California	729,000	NA
Colorado	6,005,000	NA
Idaho	479,000	814,000
Montana	10,576,000	17,351,000
Nevada	899,000	NA
New Mexico	1,129,000	NA
Oregon	912,000	1,183,000
Utah	366,000	NA
Washington	605,000	1,039,000
Wyoming	9,785,000	14,457,000

Source: Gridded State Maps of Wind Electric Potential, *Pacific Northwest Laboratory, 1992,* and *True Wind Solutions High-Resolution Wind mapping project for NorthwestSEED, 2002.*





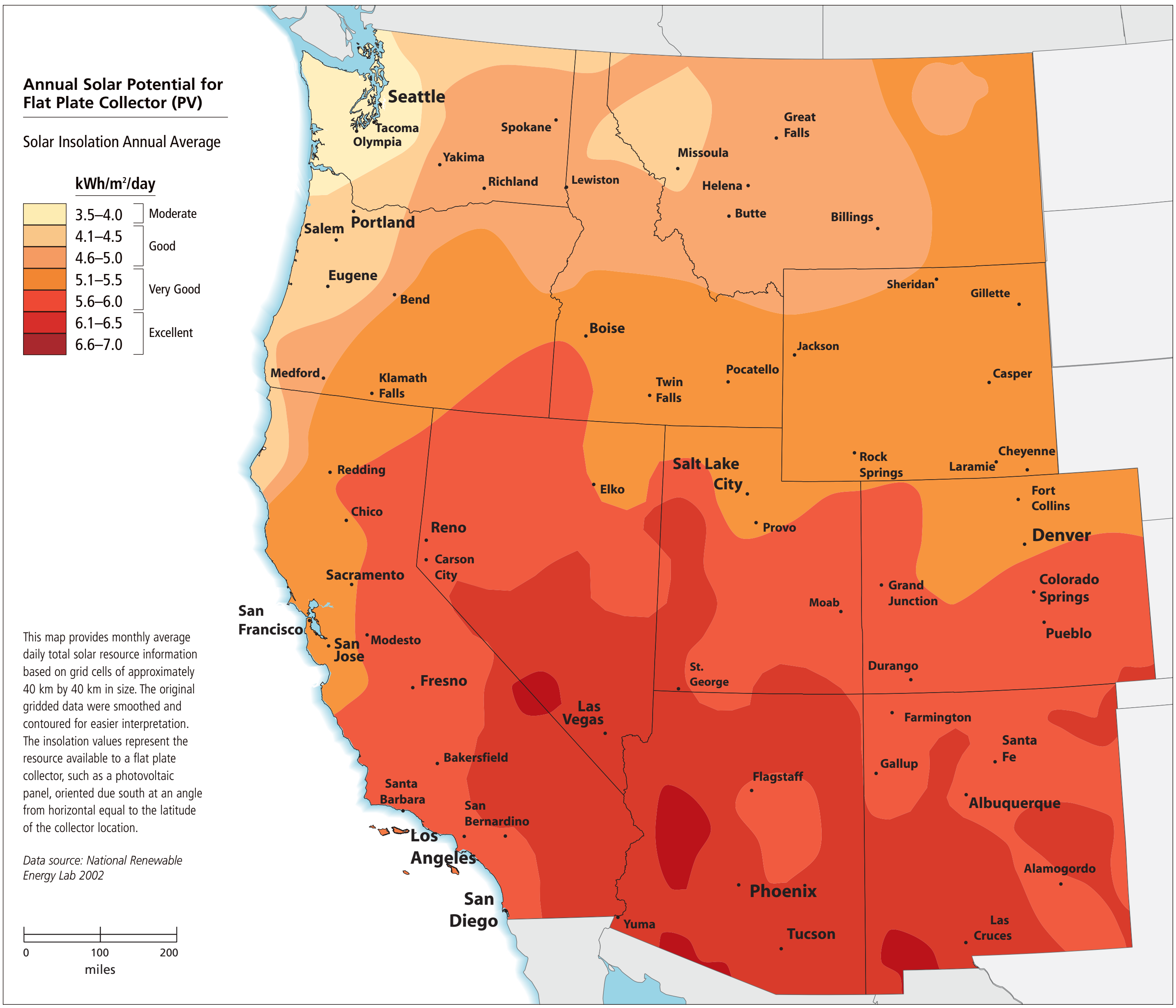
Wyoming 1987 and 2002

Wyoming is one of five states with an updated 2002 wind resource map. The 2002 map (right) shows far greater detail than the 1987 map (above). The dramatic difference can be attributed to a decrease in the spatial resolution, or "cell size," used to map the data. The newer data contain about 4,000 times more detail.

Solar

Solar energy is one of the most abundant natural forms of energy. Thousands of buildings across the West use passive solar design, solar hot water systems, photovoltaics, or other types of solar collectors to provide a portion of their energy. This map demonstrates the potential energy available for directly converting the sun's *light* into electricity using photovoltaics. Electricity can also be generated from the sun using concentrating solar technologies – those that turn the sun's *heat* into electricity.

At least 371 MW of solar power are currently installed in the West. Of this, 21 MW are photovoltaics and 350 MW are concentrating solar power.

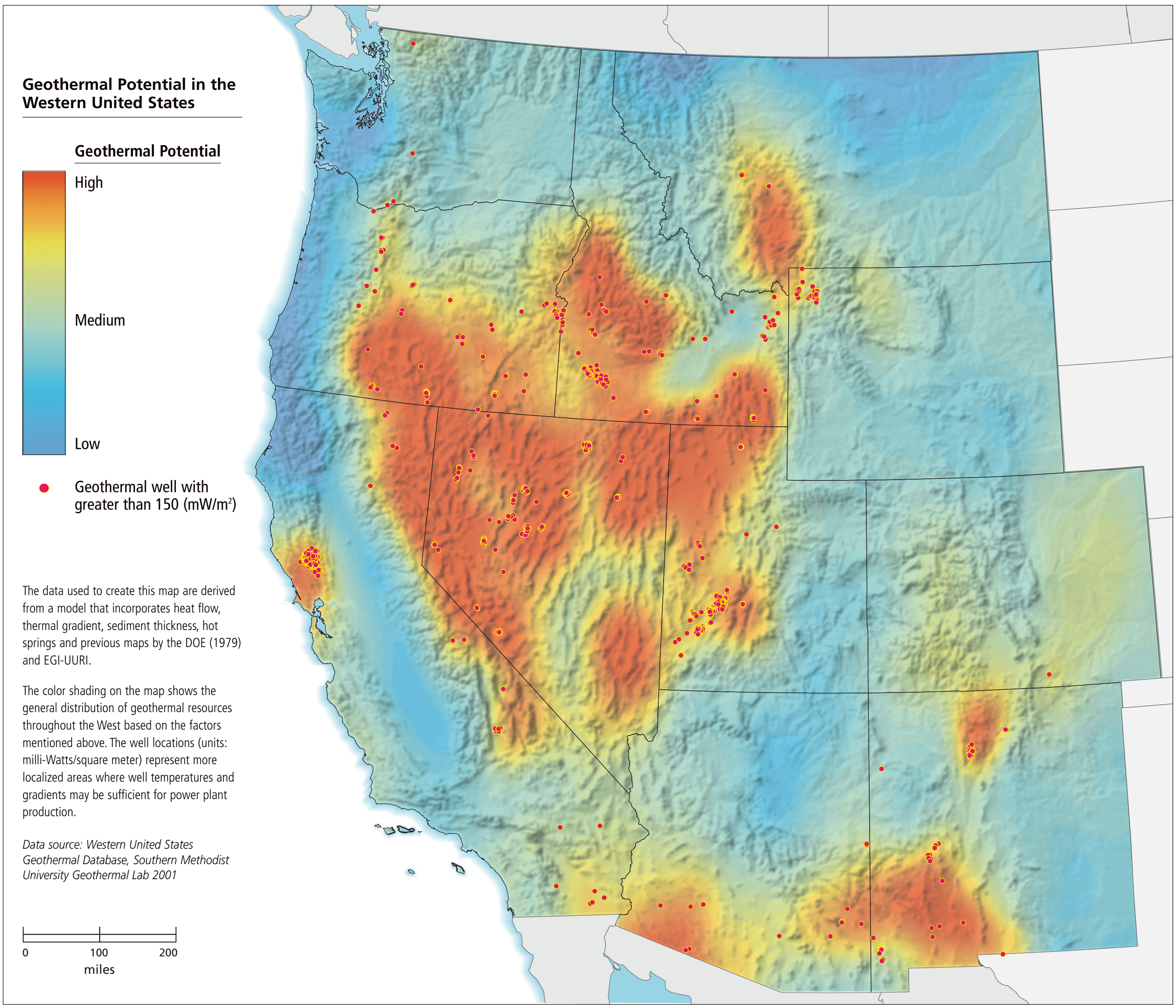


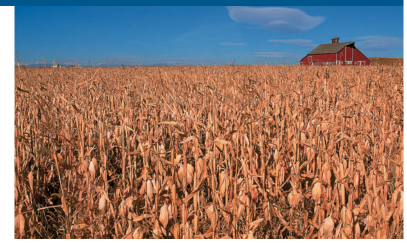
Geothermal

The potential for geothermal energy – heat from the earth – is significant worldwide. It is estimated that the uppermost six miles of the Earth's crust contains many times the energy of all oil and gas resources in the world. In the US, geothermal is found almost entirely in the West.

Geothermal is commonly used both for direct heating and cooling and to produce electricity. Geothermal heat pumps, which exchange heat between the earth and a home or business, are useful in most areas of the West and are not dependent on the same type of resources as large-scale geothermal electricity production.

There are 2,734 MW of geothermal power plants currently installed in the West.



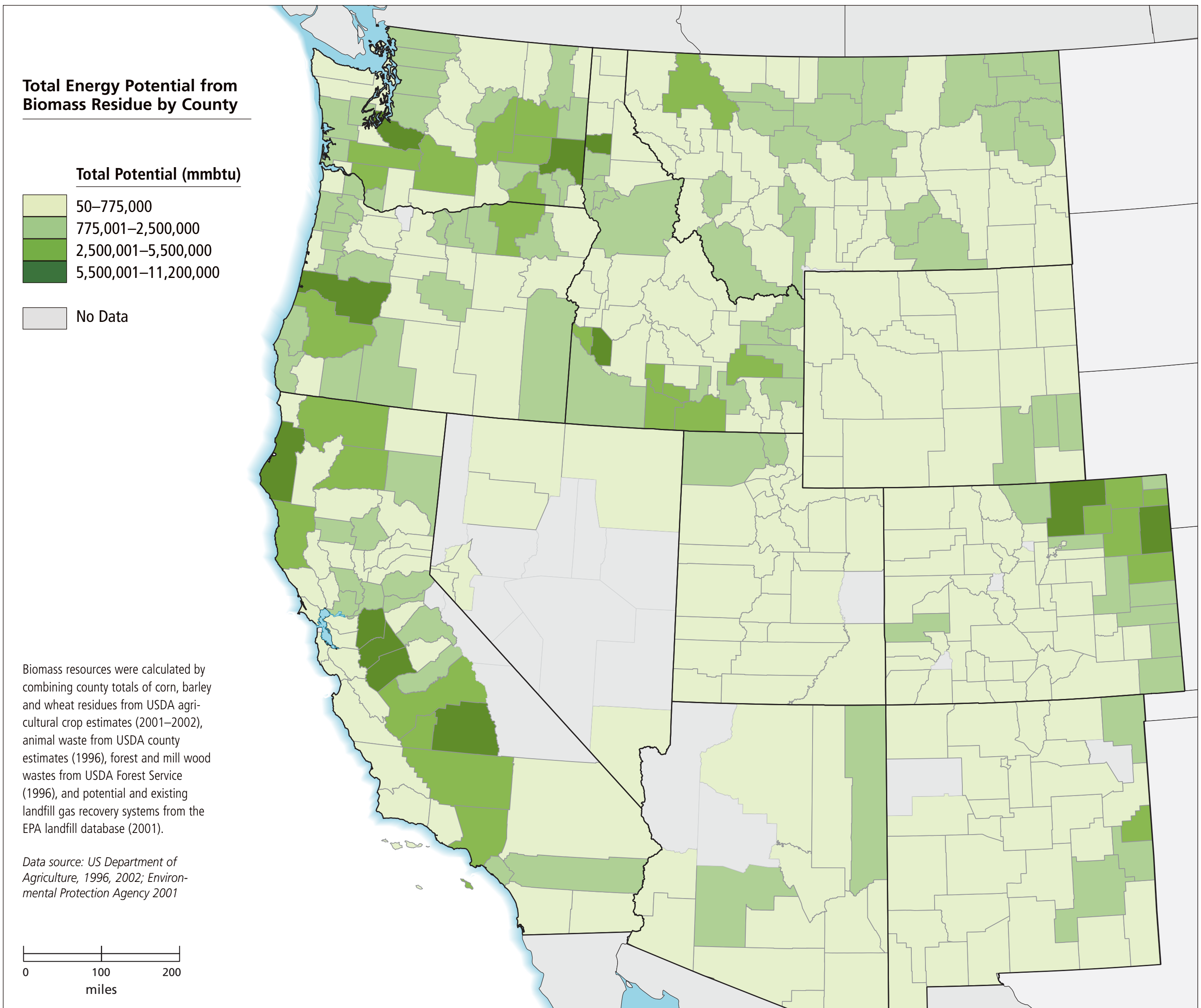


Biomass

Biomass energy (or bioenergy) uses organic materials such as agricultural and forest residues, animal waste, and landfill gas (methane) to produce electricity. Biomass can be used in its solid form for heating applications or electricity generation, or it can be converted into liquid or gaseous fuels, e.g., turning corn into ethanol for gasoline.

In many applications, biomass utilizes organic material that would otherwise be added to landfills or burned without capturing the embodied energy. Fast-growing, drought-resistant "energy crops" may become the biomass fuels of choice in the future. In the West their development is likely to be limited to less arid locales.

The eleven Western states currently have 1,747 MW of installed capacity of biomass.



Biomass resources were calculated by combining county totals of corn, barley and wheat residues from USDA agricultural crop estimates (2001–2002), animal waste from USDA county estimates (1996), forest and mill wood wastes from USDA Forest Service (1996), and potential and existing landfill gas recovery systems from the EPA landfill database (2001).

Data source: US Department of Agriculture, 1996, 2002; Environmental Protection Agency 2001

Electric Generation Potential from Renewable Energy

Electricity generated by renewables today represents only a very small fraction of the total potential. Theoretically, available wind, solar, geothermal, and biomass resources could supply several times the West's electricity needs. Renewables can generate some of this electricity at competitive costs, especially from wind. Other resources will require appropriate policies to yield cost reductions, such as those expected for solar photovoltaics and biomass gasification, by accelerating market development and spurring widespread implementation to create economies of scale.

Given many unknowns about the pace of future technological progress and electricity market conditions, it is difficult to predict exactly how much of the region's electricity might ultimately be produced from renewables over the next few decades.

For each state, the table below shows indicative electricity generation potentials by resource, compared with the overall electricity consumption in the state. The table is followed by a description of how the estimates were calculated. Additional detail is provided in the Data Sources and Methodologies section. While generation production estimates can be compared across states for any given resource, the estimates for the different resources are not directly comparable. Each resource estimate is based on different assumptions and constraints. All are subject to major uncertainties. For instance, the geothermal estimates include high-temperature sites that may prove unexploitable due to competing land uses and more recent and inconclusive test drilling. However, the geothermal estimates do not include the lower-temperature resources that can now be tapped using binary cycle technology. Evaluating solar generation potential is also challenging, since the theoretical resource is vast and the achievable potential hinges on policy commitments, future cost reductions, and application approaches.

Electricity Production from Renewable Sources (Illustrative Potentials) Compared With Current Consumption (million MWh/yr)

State	Illustrative Potentials				Current (1999)
	Wind	Solar	Biomass	Geothermal	Electricity Consumption
Arizona	5	101	1	5	58
California	45	128	14	59	235
Colorado	601	83	4	0	41
Idaho	49	60	9	5	23
Montana	1,020	101	6	N/A	13
Nevada	55	93	1	20	26
New Mexico	56	104	0	3	18
Oregon	70	68	10	17	48
Utah	23	69	1	9	22
Washington	62	42	11	0	99
Wyoming	883	72	0	N/A	12
TOTAL	**2,869**	**920**	**57**	**118**	**594**

Wind

Wind calculations are based on "windy land area," defined as areas with an average wind power of Class 4 or greater. In general, wind regimes of Class 4 or higher are considered economically viable for utility-scale wind projects. However, because of terrain, land-use restrictions, or environmental sensitivities, not all windy land is suitable for wind energy development. In the estimates presented below, areas not suitable for wind power production were screened out. (Small-scale distributed wind turbine systems require less wind for economic viability and have been successfully installed in regimes as low as Class 2. Potential energy production from small-scale turbines located in lower class wind regimes, however, are not reflected in the table.) These estimates were developed using the most recent available data for each state (2002 for ID, MT, OR, WY and WA, 1997 for NM, 1995 for CO and 1987 for the others).

Solar

The amount of solar energy that strikes the United States is much greater than that needed to meet our foreseeable energy needs. To give an idea of the tremendous theoretical potential of solar power production, the estimates presented here show the amount of electricity that could be generated if solar photovoltaic systems were installed on 0.5% of each state's total land area. As the table (pg. 13) shows, even restricting solar development to this small percentage of total land would yield large generation potentials – in many cases more than the electricity currently consumed in the state. While solar's theoretical potential is enormous, the high cost of solar power – currently in the 25–30 cent/kWh range – limits the use of solar energy in most applications. If these potentials are to be realized solar costs must come down. Until costs are reduced, solar power is most likely to be developed in areas with high electricity costs, where solar's ability to generate during summer peak hours is most valued, and in off-grid applications, where the expense of electric line extensions make distributed solar technologies cost-effective.

Geothermal

Deriving comprehensive estimates for geothermal energy's potential is particularly difficult because geothermal heat lies buried, often at significant depth, and is not easily modeled and verified with available tools. Although temperature gradient maps like those shown on page 11 can show "hot spots" where conditions for effective power generation are most likely to occur, the geological conditions needed for actual power generation (hot fluids at high flow rates) cannot typically be determined without expensive on-site test drilling. Over the past two decades, test drilling activity has been limited, and where done, results are often proprietary. As a result, available knowledge on resources amenable to power generation has not increased significantly since the US Geological Survey published its widely cited Circular 790 in the late 1970s.

Advances in geothermal power technologies since that time have rendered some lower temperature resources more amenable to power generation. However, there are no comprehensive assessments of these resources to add to power production estimates.

For the purposes of power estimates presented here, we relied upon data developed for the US DOE's National Energy Modeling System (NEMS), a collection of estimated resources and development costs at approximately 50 sites in the Western US. These data were derived from the earlier USGS analysis and have been subsequently revised by geothermal experts. These estimates are still speculative. There is a significant difference of opinion in the geothermal field as to the total exploitable resource, especially given potential land-use conflicts at a number of sites.

Biomass

Biomass energy is widely used for power generation in the West, particularly from residues at paper and pulp mills and from methane captured at municipal landfills. The overall resource potential is far greater, as the region's extensive agriculture and forestry activities produce vast quantities of residues. While it would be neither environmentally or economically viable to use all of these materials for energy purposes, the sustainably exploitable resource is significant. For instance, up to 30–40% of crop residues, such as wheat stalks and corn stover, can be collected while leaving sufficient residues in the fields to maintain soil quality.

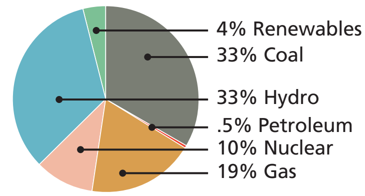
In addition to the solid biomass residues, landfill gas and animal wastes (with anaerobic digesters) generate methane that can be captured and burned in engines or microturbines. The table (pg. 13) shows the combined biomass resource from landfills and animal, crop and forest residues, in terms of total electricity generation potential.

The potential generation from these sources of biomass, presented above, represents a high estimate, since they reflect all available residues and assume that all landfills can generate electricity. However, these estimates do not reflect all potential sources of biomass energy, such as dedicated energy crops.

Status of Renewable Energy Development in the West

Electricity Generation

Over half of the West's electricity is produced by burning fossil fuels. The main sources of electricity in the West are coal, hydropower, natural gas and nuclear. In 1999, renewable resources accounted for 4% of the region's generation base.

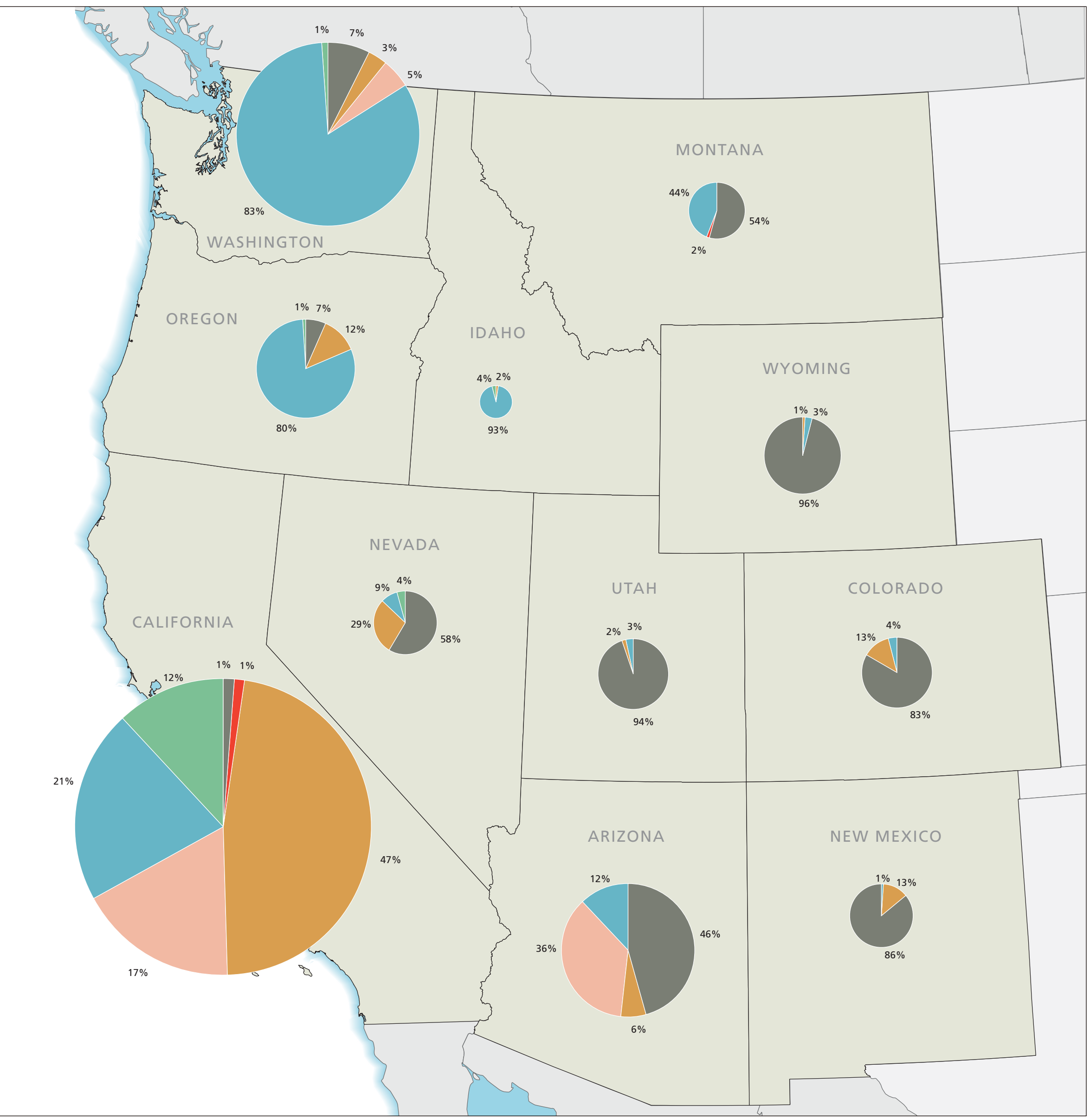


Regional Mix

This chart shows the breakdown of fuel sources used to supply the entire region's electricity. When compared to the map below, the importance of different resources to different states becomes apparent. Due to the interconnectedness of electricity transmission in the West, energy produced in one state is often consumed in another.

Energy Production by State, 1999

- Coal
- Gas
- Hydro
- Nuclear
- Renewables
- Petroleum



Total Megawatt Hours Generated

Arizona	84,000,000
California	191,500,000
Colorado	39,500,000
Idaho	14,400,000
Montana	31,400,000
Nevada	32,800,000
New Mexico	32,600,000
Oregon	56,700,000
Utah	36,800,000
Washington	117,100,000
Wyoming	43,600,000
TOTAL	**680,400,000**

Each pie chart is scaled to the total amount of energy produced.

Data source: Energy Information Administration 1999

0 100 200
miles

Renewable Energy Facilities – Installed Capacity

State	Installed Capacity of Renewables (in MW)
Arizona	9
California	5,481
Colorado	68
Idaho	120
Montana	16
Nevada	238

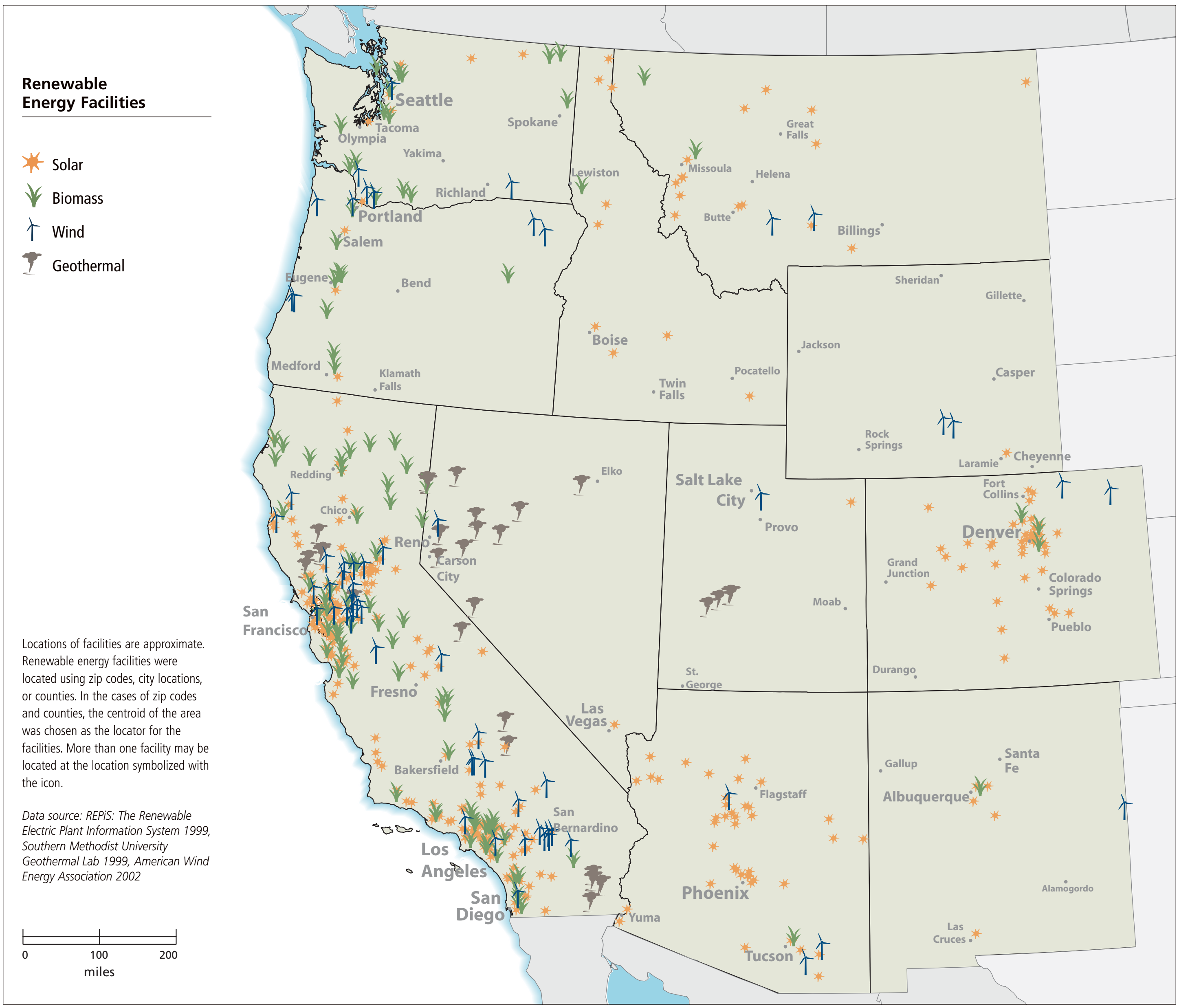
State	Installed Capacity of Renewables (in MW)
New Mexico	4
Oregon	303
Utah	44
Washington	512
Wyoming	141
Total	**6,936**

The West is home to 45% of the nation's installed renewable energy capacity. California leads the country in renewables development, single-handedly comprising nearly 80% of the West's installed capacity. While the map below demonstrates California's dominance, it also shows the emergence of significant renewables installations in each of the other states.

Renewable Energy Facilities – Location

Renewable energy facilities, ranging from small household rooftop photovoltaic systems to large-scale geothermal power plants, have been installed across the region. The clean energy facilities shown below represent projects listed in the DOE REPiS database.

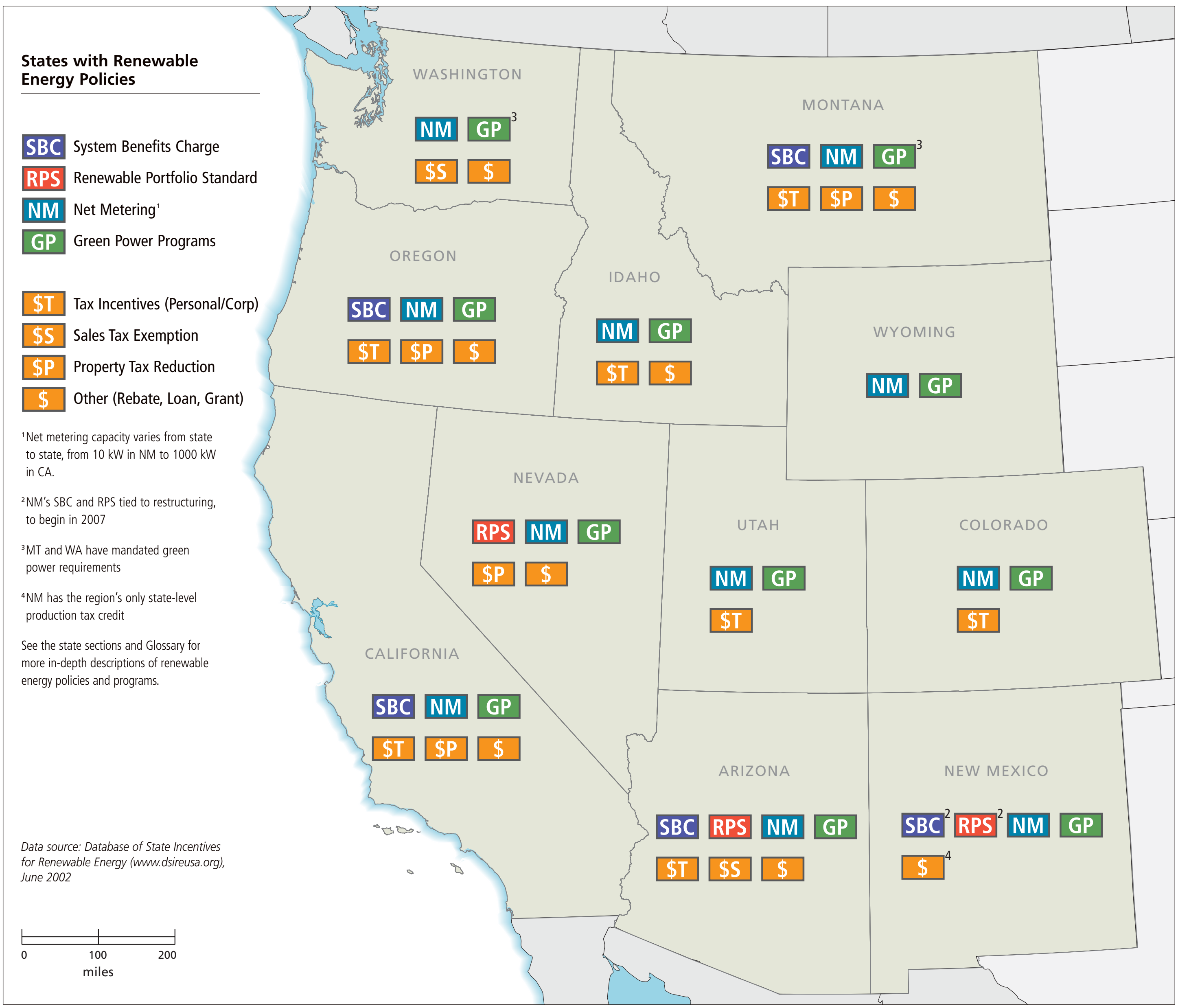
While the wind, geothermal and biomass facilities are generally utility-scale projects, the solar facilities shown here are mainly residential-scale, less than 10kW.



Policies Encouraging Renewable Energy

Across the West, a number of states have adopted policies supporting the development of renewable energy technologies. By fostering demand and providing financial incentives, these policies play a significant role in developing a market for these emerging technologies. In addition, many electricity providers and local governments have developed programs to encourage renewables, such as green power purchase options and net metering.

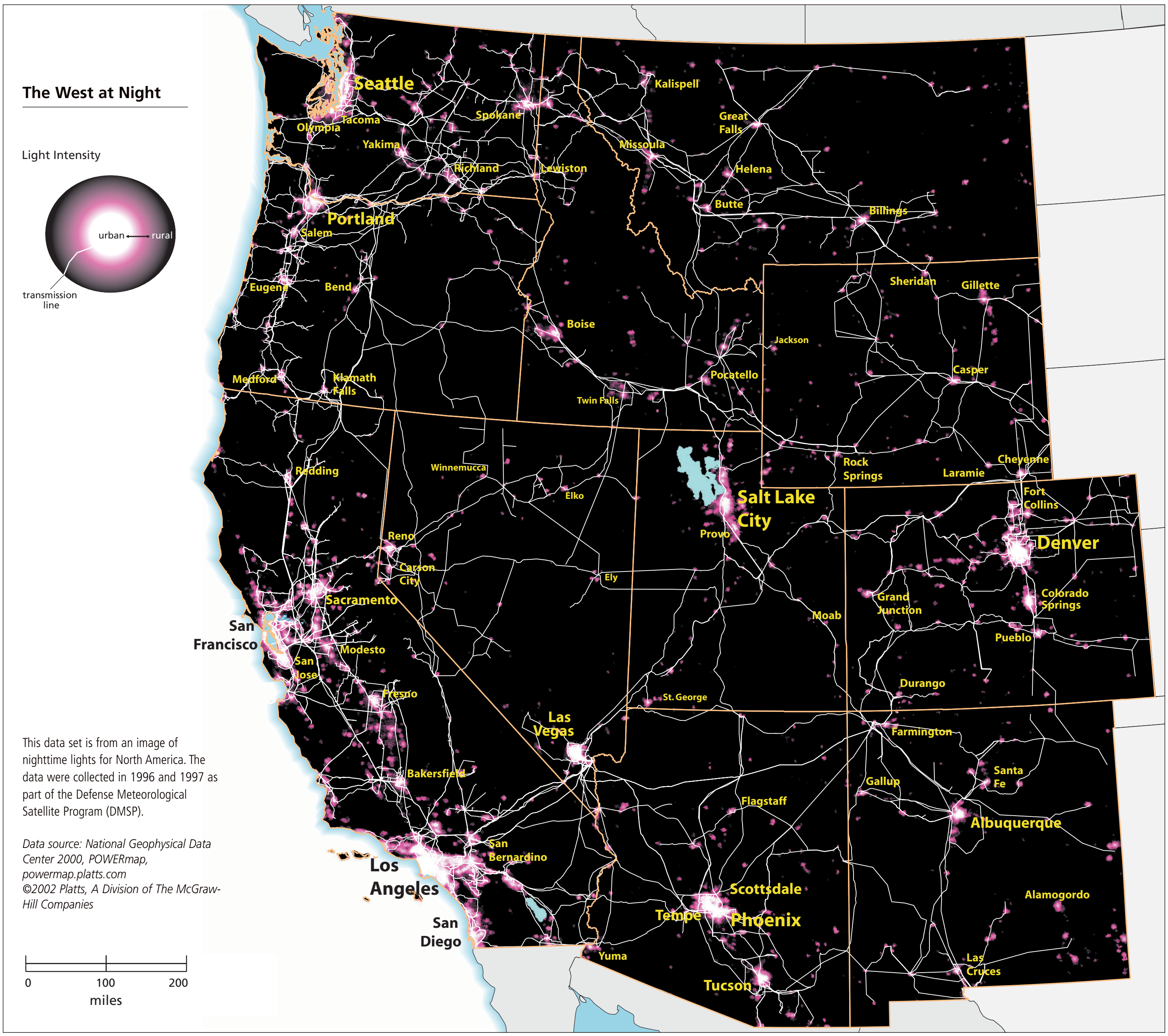
Further, new renewables are being funded by "green tags," certificates representing the environmental benefits of clean power and sold nationally. It is important to note that renewable energy policies and programs vary widely in scope and funding levels from state to state, resulting in different levels of actual development of renewables. In-depth descriptions of policies are provided in the Glossary and state sections.



Considerations in Developing Renewable Energy in the West

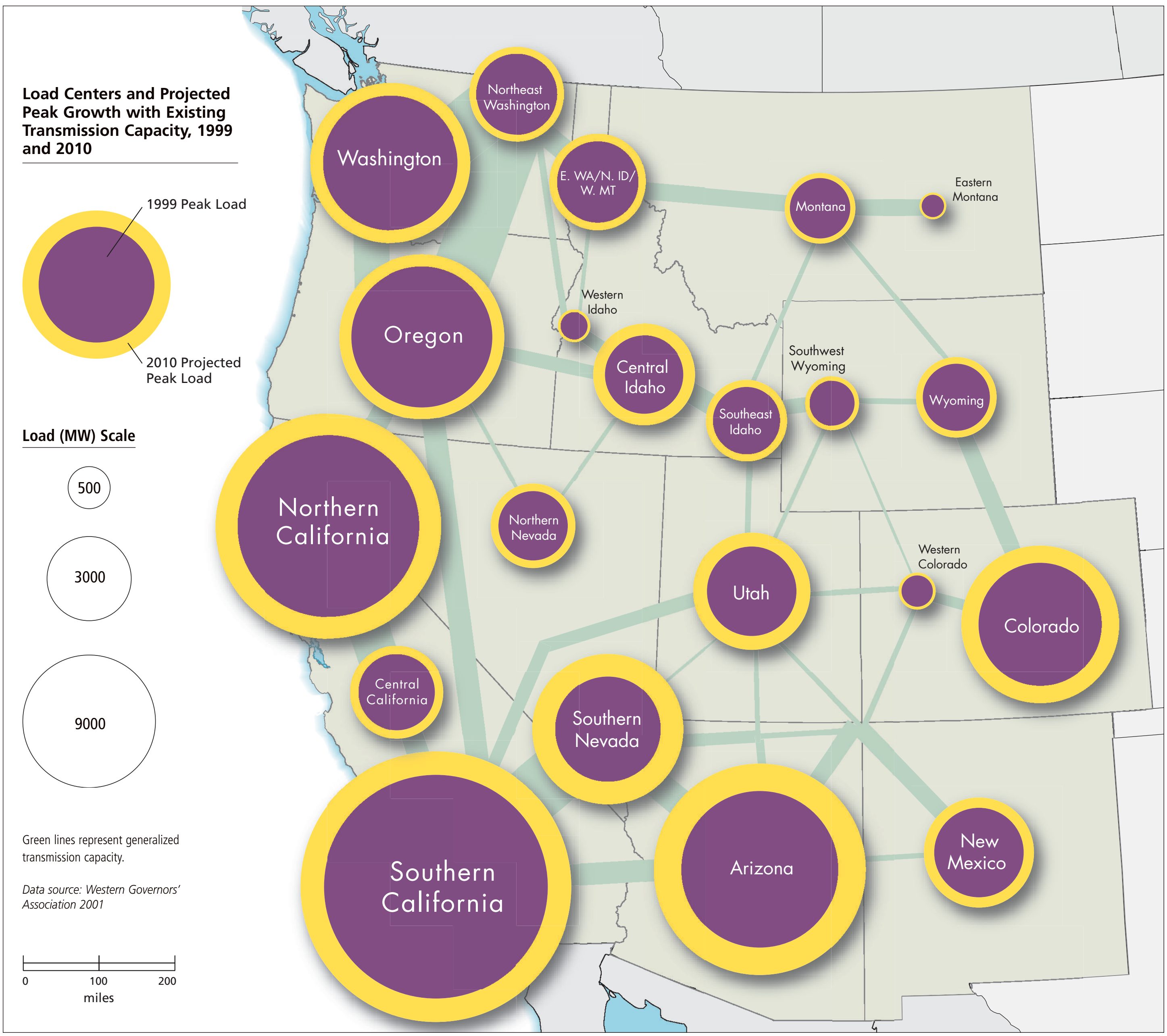
The Western Power Grid

The electric grid may well be the most impressive engineering accomplishment of our time – reliably moving power from large, centralized generating stations to businesses, factories and homes. As the West's population and economy grow, more demands are placed on this system.



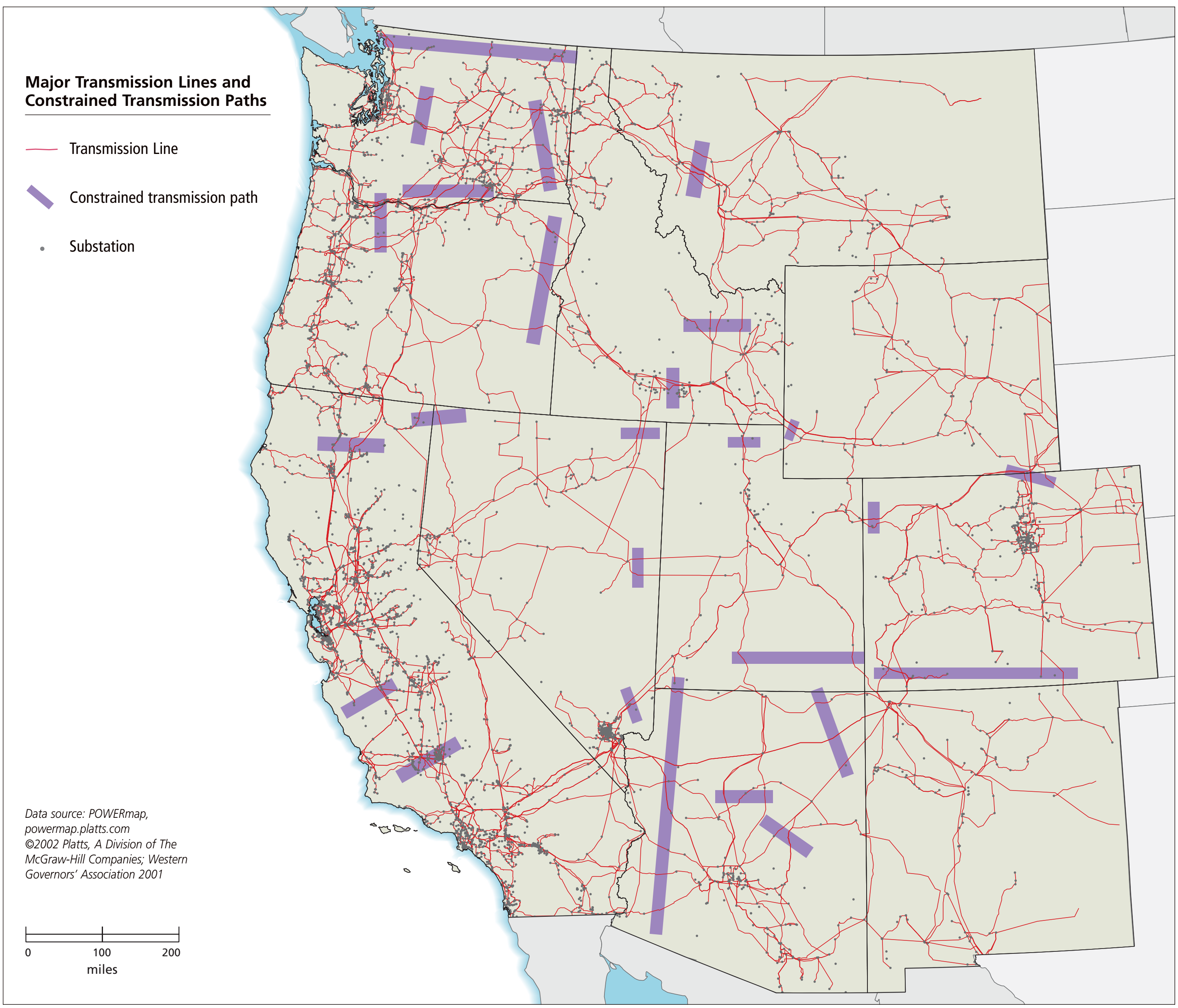
Load Growth

The West is the country's fastest growing region. By 2010 it is expected that the region will need somewhere between 30,000 and 50,000 MW of new electric resources to meet growing demands for electricity. Meeting this new resource need provides an opportunity to increase the amount of renewable energy resources in the Western power mix. Increased energy efficiency is another important resource that can help meet the region's growing electricity needs.



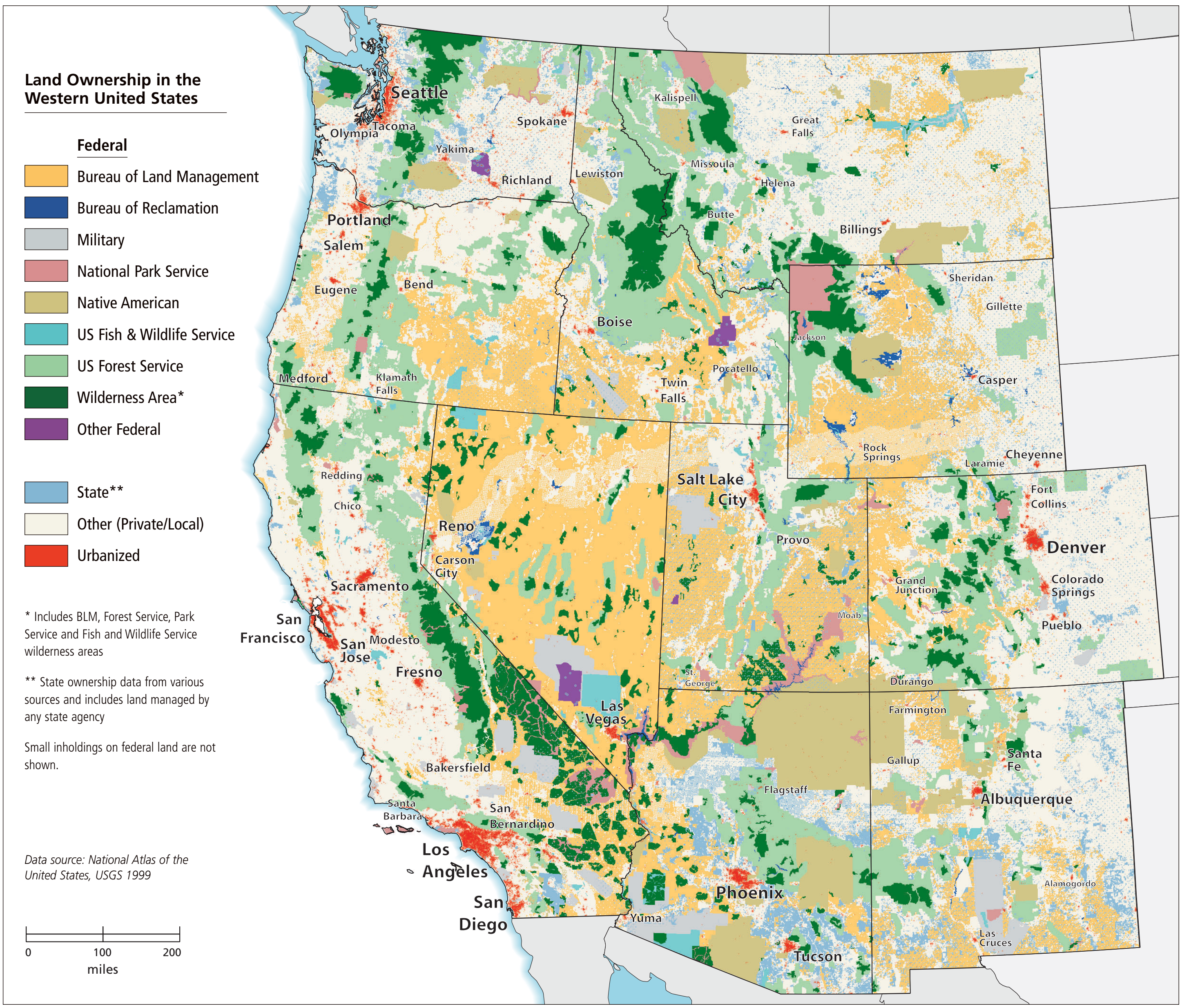
Transmission Constraints

The existing transmission system presents both barriers and opportunities to renewable energy development in the West. On one hand, access to transmission is an important component of developing large-scale wind, solar, geothermal, or biomass facilities, which are often sited far from load centers. As wholesale electric markets have developed over the last decade and electric demand has grown, many major transmission paths across the West have become increasingly constrained, at least during some hours of the year. Absent new transmission system investments or changes in how existing transmission capacity is allocated, transmission constraints may limit large-scale renewable energy development in the region. On the other hand, some renewable resources can be installed near load centers and may gain an economic edge due to their ability to ease congestion.



Land Use Considerations

The West is blessed with an abundance of renewable energy resources. It is also blessed with wildlands, habitat critical for wildlife, sensitive watersheds, recreation areas, and cultural and historical sites. Renewables development must be done in an environmentally and culturally sensitive manner to ensure that the West's tremendous natural heritage is not diminished. Extensive land ownership data can help guide decisions regarding appropriate areas for development of renewables.

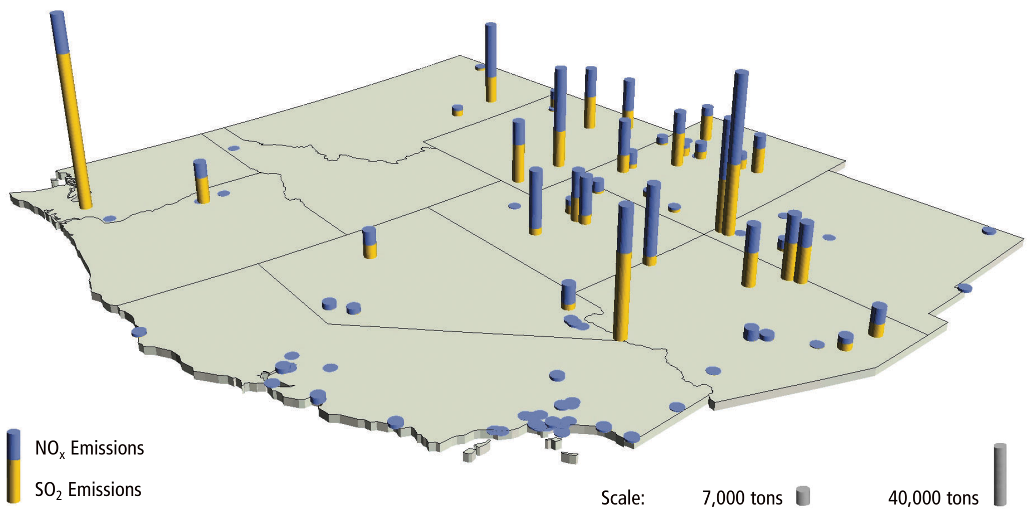


Environmental Impacts of Fossil Fuels

Much of the West's electricity is generated by burning fossil fuels in power plants. The effects are broad in scope, from the land-use impacts of coal and gas extraction to the public health consequences of poor air quality. A major advantage of renewable resources is their lack of harmful air emissions. Burning fossil fuels in power plants accounts for 63% of US SO_2 emissions and 20% of US NO_X emissions, contributing to regional haze, urban brown clouds, and acid rain. Electricity generation also produces 40% of US CO_2 emissions, the greenhouse gas considered the primary contributor to global warming.

Power Plant Emissions, 2000

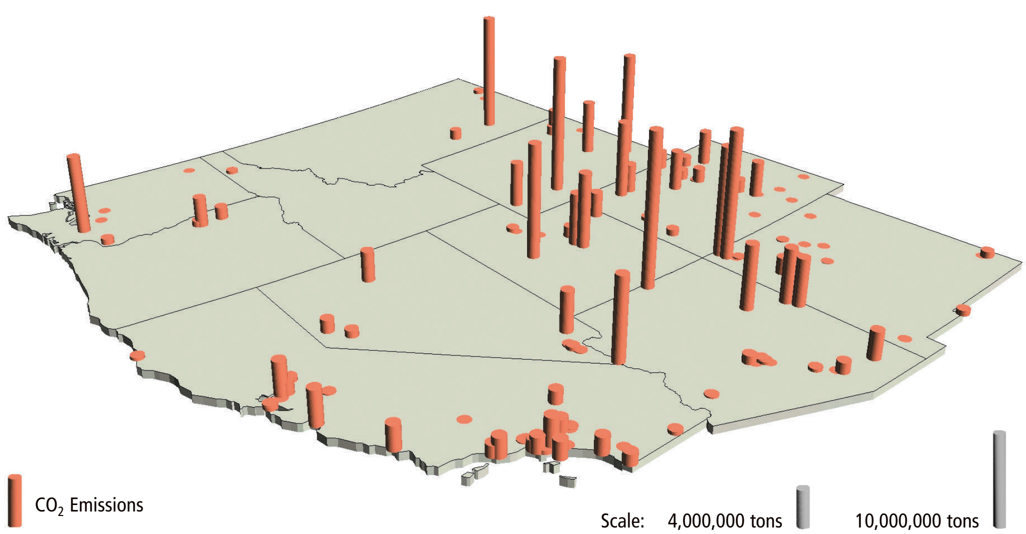
Each bar represents the location of a power plant regulated under the EPA's Acid Rain Program (Title IV). The height of the bars is scaled to reflect the emissions levels for each plant. Because CO_2 emissions are so much higher than either SO_2 or NO_x, different scaling factors were used to determine the height of the bars.



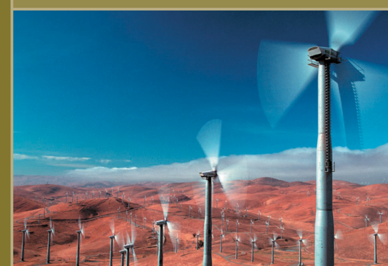
Total Emissions in Region from Title IV Plants, 2000

	tons
Sulfur Dioxide (SO_2)	506,662
Nitrogen Oxide (NO_X)	547,754
Carbon Dioxide (CO_2)	316,774,136

Data source: EPA Acid Rain Program (Title IV) Emissions Scorecard, 2000

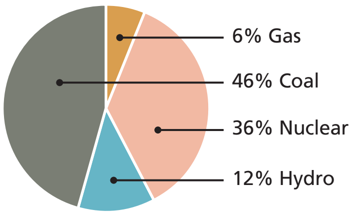


State Summaries



Arizona Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

Renewable Energy Policies

SBC System Benefits Charge
Arizona Public Service (APS) and Tucson Electric Power (TEP) each have an SBC used to partially meet requirements under the RPS and fund other public interest programs.

RPS Renewable Portfolio Standard
0.2% at start (2001), 1.1% by 2007. Solar to meet 50% initially, 60% by 2004.

NM Net Metering
Maximum capacity set by utilities: TEP – 100 kW, APS – 10 kW. APS' program is "net billing," requiring the use of dual meters.

GP Green Power Programs

$T Personal/Corporate Tax Incentives

$S Sales Tax Exemption

$ Rebate, Grant or Loan Program

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

58 million MWh

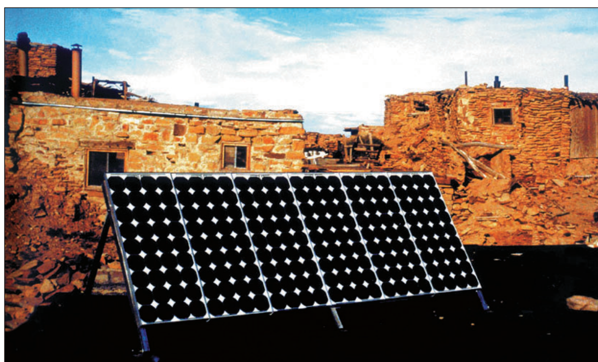
Arizona is often called the "solar capital" of the US. Despite the state's tremendous solar and other renewable resources, Arizona lags behind the rest of the region with only 9 MW of installed renewable energy facilities. However, thanks to the passage of a renewable portfolio standard designed to boost the development of renewables, especially solar, across the state, a number of new large-scale solar projects are now under construction. The RPS requires utilities to obtain nearly 1% of their power from renewables, half of which must be from solar.

Renewable Energy Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	.04 MW
Solar (PV)	4 MW
Solar (Thermal)	.08 MW
Geothermal	0 MW
Biomass	5.3 MW
Total	**9.4 MW**

[1]*Source: REPIS database, plus known installations*

NativeSUN – Solar Power on Indian Lands



Photovoltaic System on the Hopi Reservation

Photo: NativeSUN

In 1985, the Hopi Foundation began a new solar electric enterprise called NativeSUN. This project was one of several designed to help the Hopi become a self-sufficient community. According to Doran Dalton, the chair of the Hopi Foundation, NativeSUN's mission is not only to provide needed electrical services and bring training and economic development opportunities to Native Americans in the Southwest, but also to accomplish this with technologies and approaches that are consistent with tribal cultural, traditional and religious norms.

By installing photovoltaic panels on homes and businesses where thousands of Hopi live without electricity, NativeSUN became an overwhelming success. The cost of a NativeSUN PV system ($5,000–$15,000) is far less than the cost to extend the electric grid to serve a home in these communities (nearly $40,000 per mile).

NativeSUN also brings much needed jobs and capital investment to the reservation – to date more than 450 systems have been installed. NativeSUN sells its solar electric renewable credits to Arizona Public Service Company to help the utility meet its goals under the state's RPS.

Solar

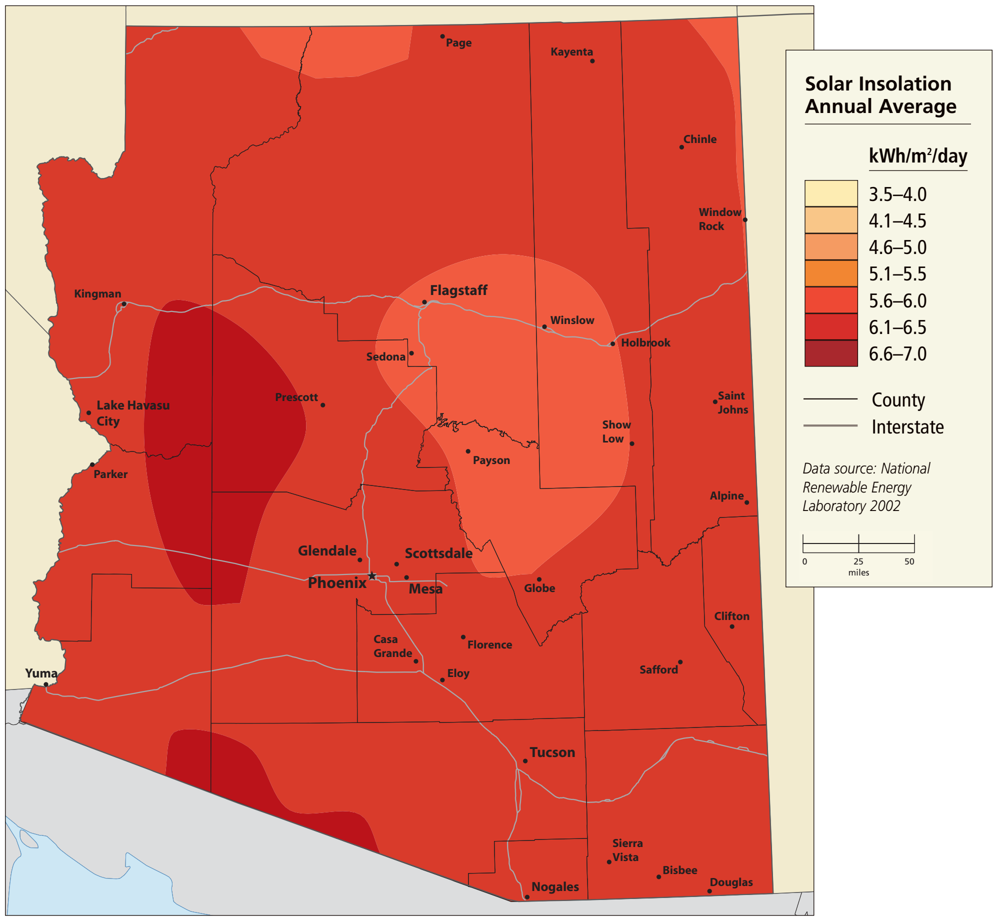
In addition to the thousands of small-scale solar photovoltaic (PV) installations found across Arizona, a number of larger scale solar projects have been developed or are in the planning stages. Solar PV provides an economical way to bring electricity to areas of the state out of reach of the grid. Grid-connected PV has the added value of reducing peak summer time electric loads.

Electricity Generation Potential: 101 million MWh/yr.

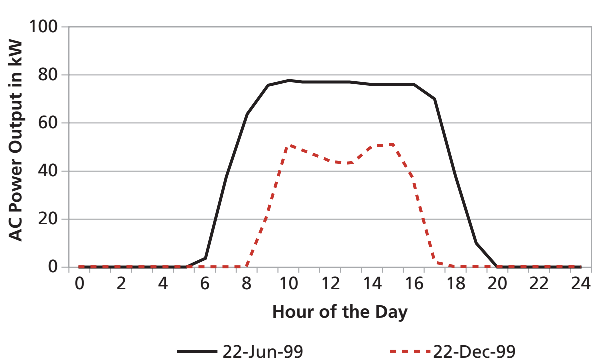
Arizona Public Service Company's Solar Dish

Arizona Public Service (APS) is evaluating the performance of the latest in Dish Stirling Solar power systems at its STAR Research Center in Tempe. This new technology, capable of producing 25kW of electricity, uses mirrors to focus sunlight onto a thermal receiver. This highly efficient solar system also can use alternative fuels instead of the sun's heat, so power can be made any time, day or night.

Photo: Bill Timmerman



Hourly PV Performance at APS Flagstaff Site



Output from a 79 kW PV System in Flagstaff

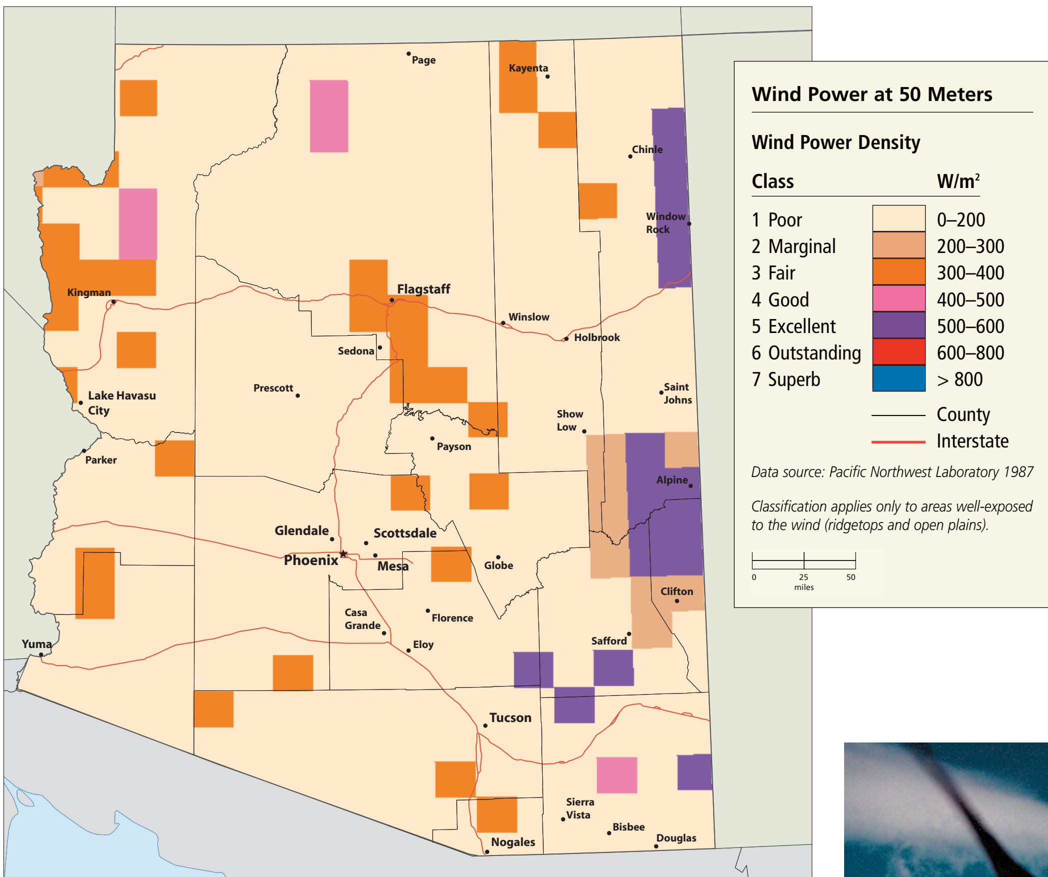
This chart demonstrates the variations in power produced by a PV system in northern Arizona. The amount of power is clearly affected by time of year and day. It is important to note the system produces its maximum output consistently throughout the day, especially during peak afternoon hours in the summer months when demands on the electric system are greatest.

Source: Solar Electric Power Association's TEAM-UP Photovoltaic Data Summary and Analysis for Arizona Public Service

Wind

This map shows 1987 wind data, the most recent available for Arizona. While modern resource modeling techniques will give more detail, this map shows promising areas for large-scale wind development along the eastern border. Rural Arizonans have also been able to rely on small-scale wind generation to supplement their electricity needs. Less than 1 MW of wind power is currently online in Arizona, but there are over 75,000 acres of windy land.

Electricity Generation Potential: 5 million MWh/yr.

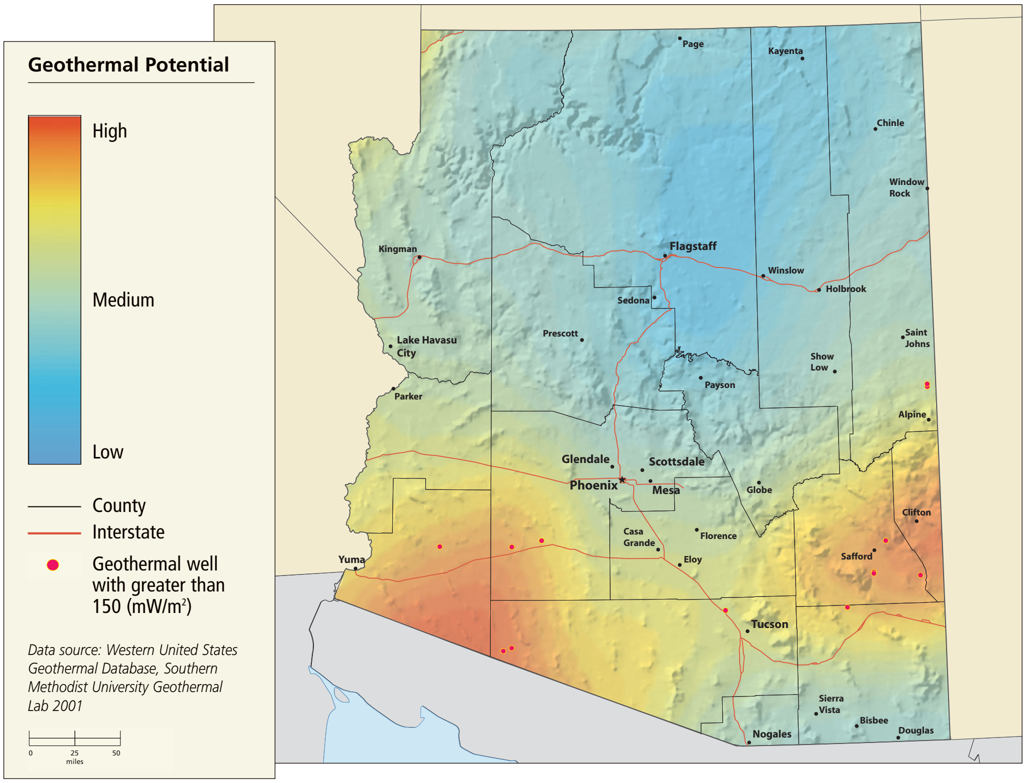


Small wind turbine

Small wind turbines like this Air 403, manufactured by Southwest Windpower, can be used for applications such as charging batteries on recreational vehicles and supplementing the electricity supply for a home, thereby lowering utility bills.

Photo: Southwest Windpower

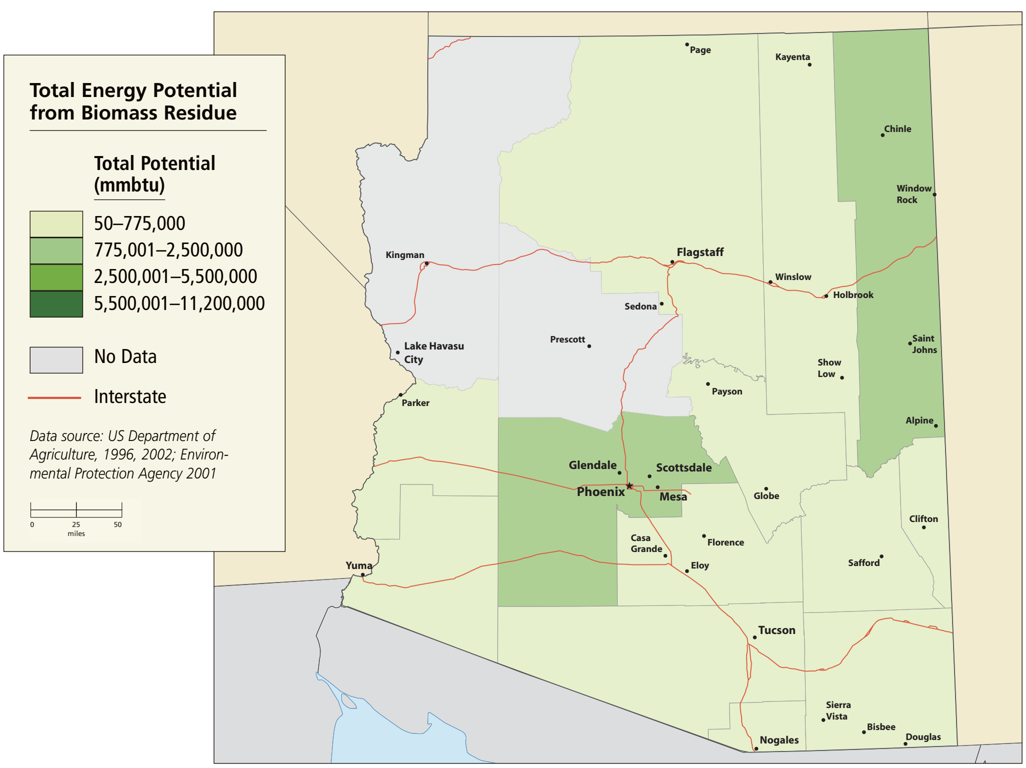
Geothermal



Arizona's geothermal resources, found almost exclusively in the southern half of the state, are a potential source of electricity and direct heating and cooling. There are currently no geothermal installations producing electricity in the state.

Electricity Generation Potential:
5 million MWh/yr.

Biomass

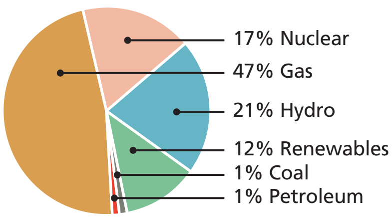


As an arid state, Arizona does not produce a high volume of agricultural crops or forest residues. However, producing electricity from landfill gas or animal wastes currently provides about 5 MW of electricity.

Electricity Generation Potential:
1 million MWh/yr.

California Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

Starting in the 1980s, California was a world leader in renewable energy, launching the world's wind and solar thermal power industries. With the move to deregulated markets however, progress on renewables has slowed dramatically. Market turmoil in 2000-2001, combined with aggressive financial incentives, have boosted interest in photovoltaics and small-scale wind power.

Renewable Energy Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	1,744 MW
Solar (PV)	15 MW
Solar (Thermal)	345 MW
Geothermal	2,456 MW
Biomass	911 MW
Total	**5,481 MW**

[1]Source: REPIS database, plus known installations

Renewable Energy Policies

SBC System Benefits Charge
$535 million raised annually for renewables

NM Net Metering
Maximum capacity: 1 MW (bi-directional time-of-use pricing)

GP Green Power Programs

$T Personal/Corporate Tax Incentives

$P Property Tax Exemption

$ Rebate, Grant or Loan Program

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

235 million MWh

Rebates and Tax Credits at Work

Small-Scale Wind Installation

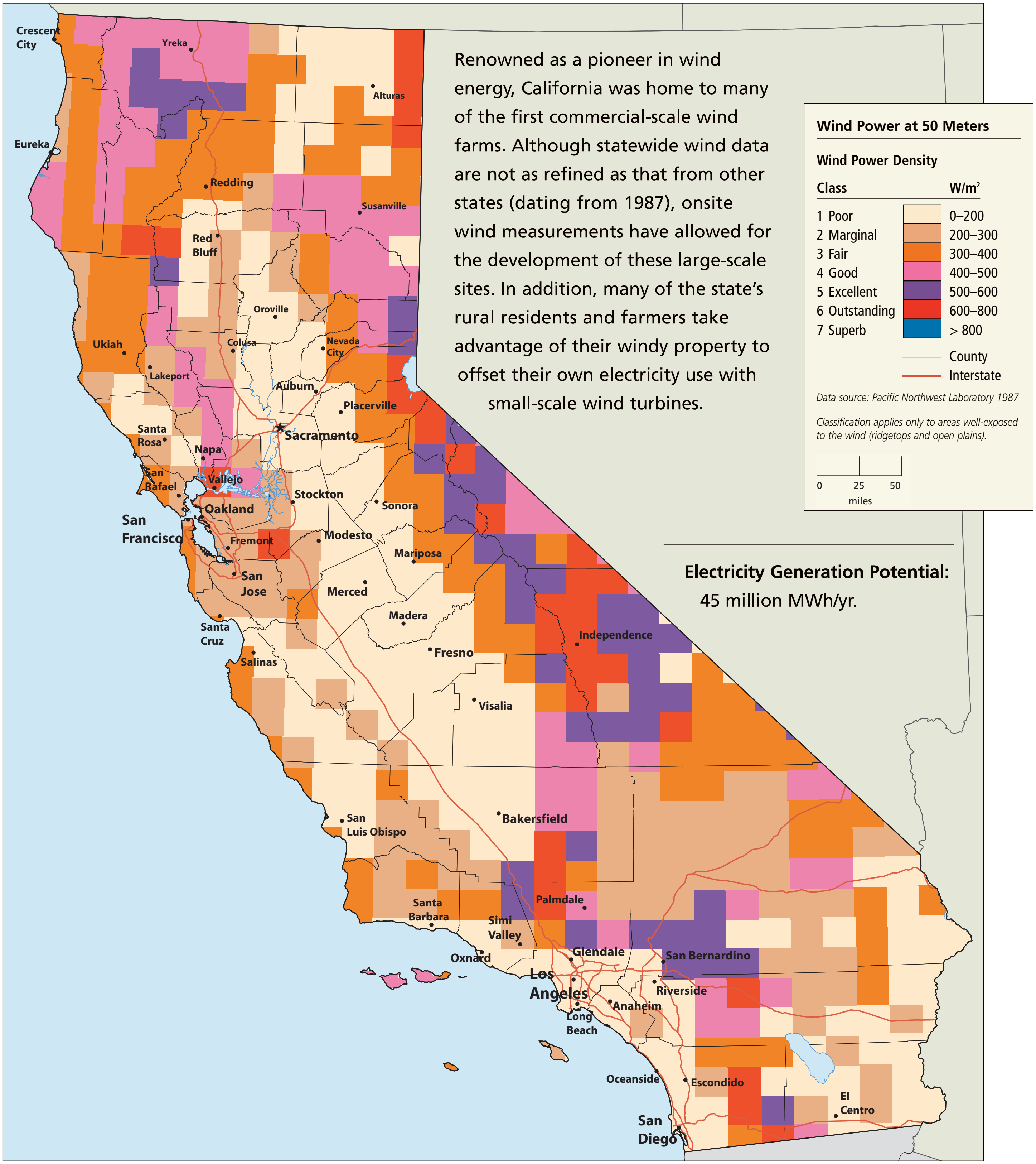
Photo: Joseph Mathewson, H&M Vineyards

Buydown programs, tax breaks and net metering are making renewable energy systems more affordable for California residents and business owners. For example, the California Energy Commission (CEC) currently offers a rebate of up to 50% on the purchase price of small-scale wind, PV, solar thermal or fuel cell systems. David Colley, a landowner in Tehachapi, collected the CEC rebate when he installed a 10 kW Bergey turbine in March 2001. During its first year of operation, Colley's small wind system cut his winter electricity bills by about $150–$200/month. With the CEC rebate and the state tax credit, Colley estimates that his wind turbine will pay for itself within 7 years. With a life expectancy of over 30 years on a 10 kW wind turbine, and a 7 year payback time, Colley can look forward to over 20 years of free wind-generated electricity and thousands of dollars saved on electricity bills.

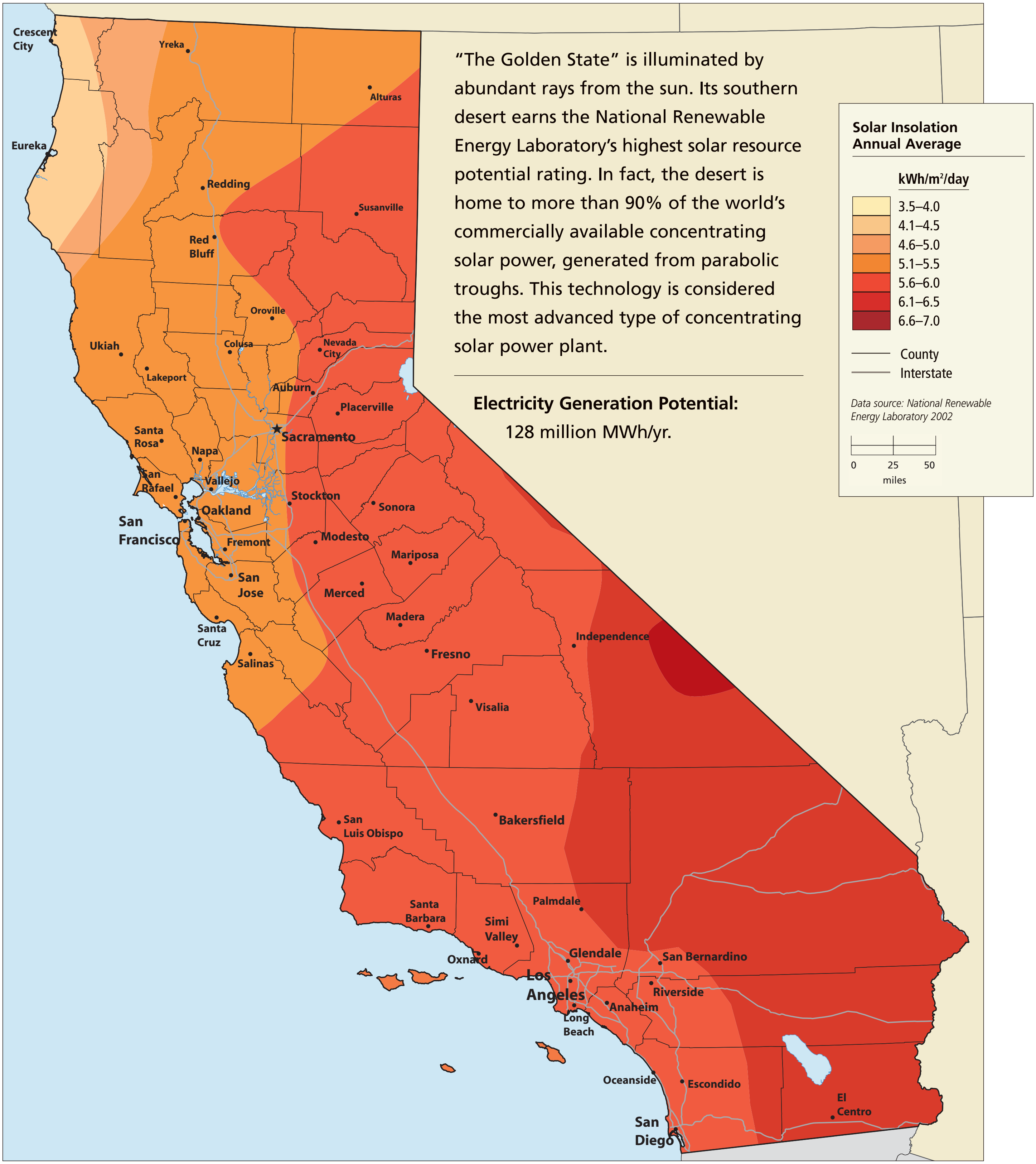
Wind

Renowned as a pioneer in wind energy, California was home to many of the first commercial-scale wind farms. Although statewide wind data are not as refined as that from other states (dating from 1987), onsite wind measurements have allowed for the development of these large-scale sites. In addition, many of the state's rural residents and farmers take advantage of their windy property to offset their own electricity use with small-scale wind turbines.

Electricity Generation Potential:
45 million MWh/yr.



Solar



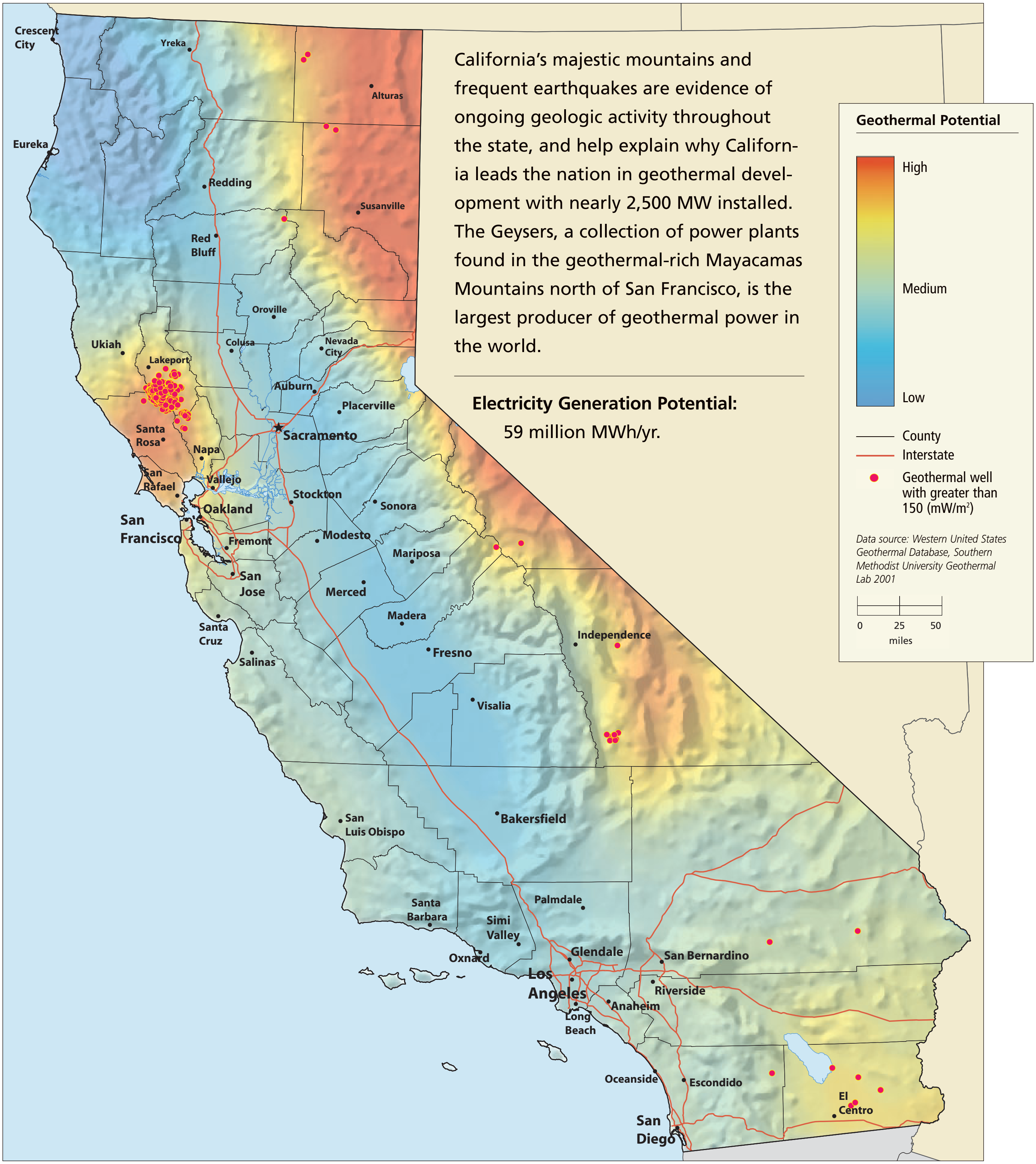
"The Golden State" is illuminated by abundant rays from the sun. Its southern desert earns the National Renewable Energy Laboratory's highest solar resource potential rating. In fact, the desert is home to more than 90% of the world's commercially available concentrating solar power, generated from parabolic troughs. This technology is considered the most advanced type of concentrating solar power plant.

Electricity Generation Potential:
128 million MWh/yr.

Geothermal

California's majestic mountains and frequent earthquakes are evidence of ongoing geologic activity throughout the state, and help explain why California leads the nation in geothermal development with nearly 2,500 MW installed. The Geysers, a collection of power plants found in the geothermal-rich Mayacamas Mountains north of San Francisco, is the largest producer of geothermal power in the world.

Electricity Generation Potential:
59 million MWh/yr.



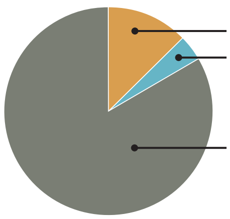
Biomass

California's agricultural industry produces large amounts of crop residues. Air pollution from openly burning these residues – a common practice – can contribute to poor air quality. Burning these residues at a biomass plant to generate electricity offers an alternative solution that benefits the environment as well as the economy.

Electricity Generation Potential:
14 million MWh/yr.

Colorado Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

Colorado's combination of high mountains and broad plains adds up to a bounty of renewable resources. Although wind power is especially abundant, electricity generated in Colorado comes primarily from fossil fuels, with over 83% produced from coal. Home to the National Renewable Energy Laboratory (NREL), Colorado is also a leader in renewable energy research and development.

Renewable Energy Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	61 MW
Solar	0.759 MW
Geothermal	0 MW
Biomass	6.125 MW
Total	**120 MW**

[1]Source: REPIS database, plus known installations

Renewable Energy Policies

NM Net Metering
Maximum capacity set by utilities: Aspen Municipal, Holy Cross Energy and the City of Glenwood Springs Electric Department – first 50 kW of PV installed; Fort Collins Municipal – 3 kW PV; Xcel Energy – 10 kW all renewables. Rural electric associations are authorized to require dual meters and to use net billing.

GP Green Power Programs

$T Personal/Corporate Tax Incentives

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

41 million MWh

Green Pricing Programs for Wind Power

Ponnequin Wind Farm on the Colorado/Wyoming Border

Photo: Warren Gretz, NREL

Xcel Energy's Windsource program and Holy Cross Energy's Wind Pioneers program have been among the greatest successes in the development of renewable energy in the US. In 1997, Xcel and Holy Cross began offering their customers the option of supporting new wind farms by paying slightly more on their utility bills (called "green pricing"). Through unique partnerships between the utilities and environmental groups, including the Land and Water Fund of the Rockies and the Community Office for Resource Efficiency, significant numbers of Coloradoans have demonstrated their support for wind power by signing up for these programs. Xcel Energy has 21,000 customers participating, including over 500 businesses. Holy Cross has one of the highest customer participation rates in the country – 5%. In response to public support for these programs, installed capacity of wind power in Colorado grew from 5 MW in 1998 to 60 MW in 2002.

Wind

Colorado has excellent wind resources with an estimated 6 million acres of windy lands, particularly on the eastern plains. There are two large-scale wind developments on line: 30 MW at the Ponnequin Wind Farm near the Wyoming border, and 30 MW at the Peetz Table Wind Farm near Sterling. Additionally, there are hundreds of good sites for small-scale applications throughout the state.

Electricity Generation Potential: 601 million MWh/yr.

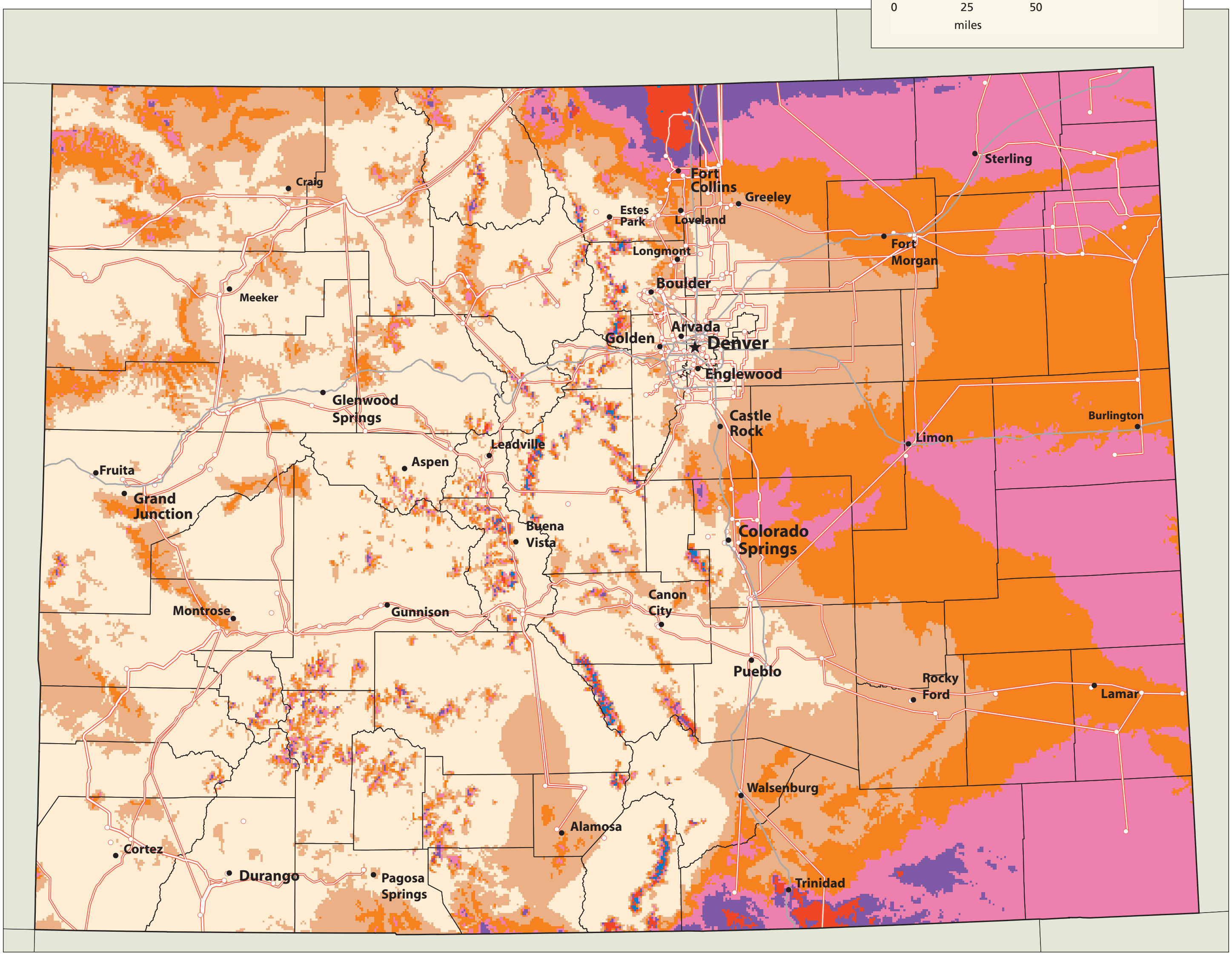
Wind Power at 50 Meters

Wind Power Density

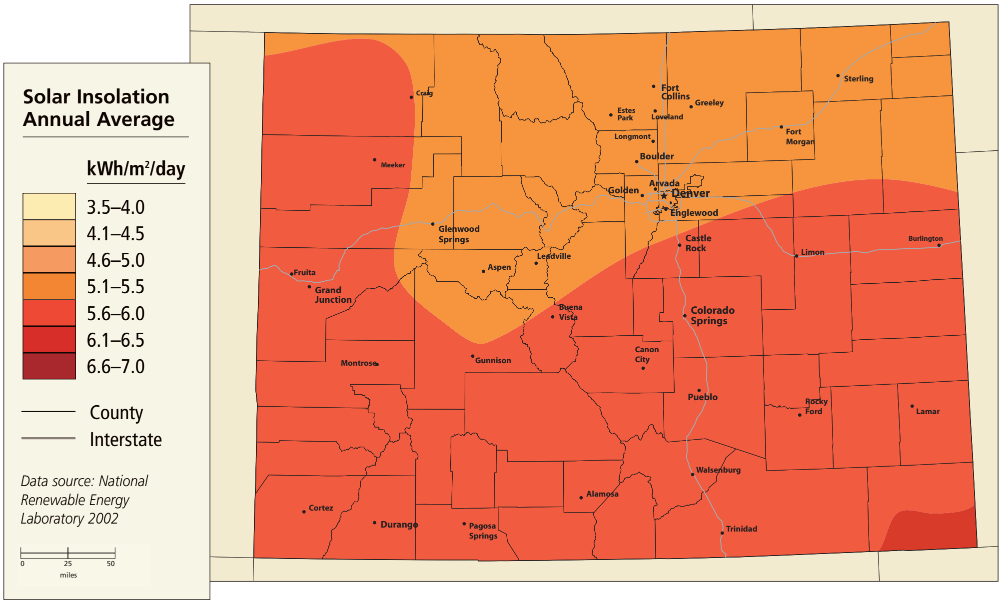
Class	W/m²
1 Poor	0–200
2 Marginal	200–300
3 Fair	300–400
4 Good	400–500
5 Excellent	500–600
6 Outstanding	600–800
7 Superb	> 800

County
Interstate
Transmission Line
Substation

Data source: Brower and Company 1995; POWERmap, powermap.platts.com ©2002 Platts, A Division of The McGraw-Hill Companies



Solar



Colorado has over 300 days of sunshine per year, making it an ideal location for solar photovoltaics and solar thermal technologies. Nearly thirty schools are tapping into the power of the sun, thanks to customers of Xcel Energy who round up their bills and/or make contributions to the Renewable Energy Trust Program.

Electricity Generation Potential: 83 million MWh/yr.

Roof-Mounted PV System at Isaac Newton Middle School

The PV system at Isaac Newton Middle School in Littleton is an example of the PV for schools program mentioned above. This 2 kW system mounted on the roof helps meet the electricity needs of the school while giving students a demonstration of clean energy in action.

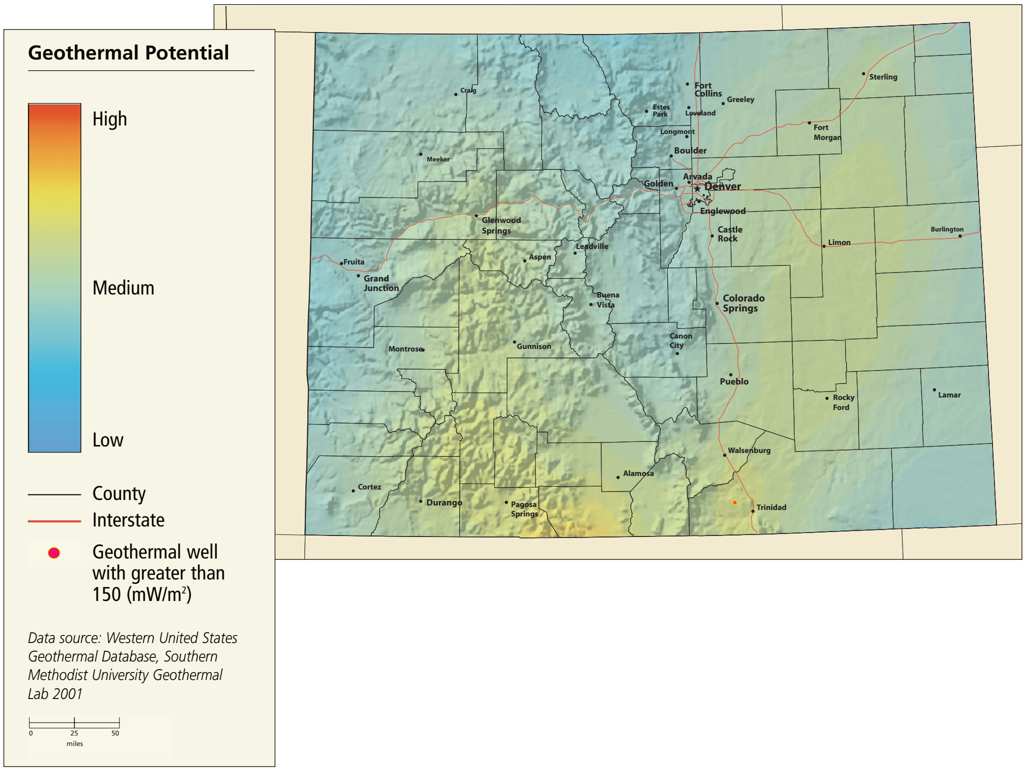
Photo: Altair Energy

Rancher Adjusting a PV Electric Fence

PV-powered fence chargers, seen here at the Aristocrat Angus Ranch, enable ranchers to move a fence from field to field along with their livestock without worrying about electricity hook-ups.

Photo: Warren Gretz, NREL

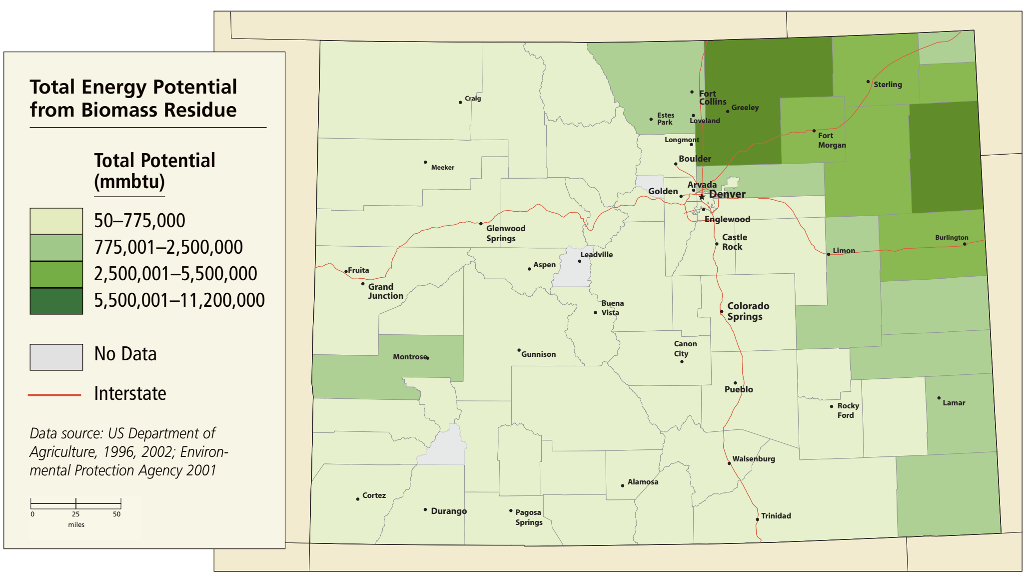
Geothermal



Colorado has moderate geothermal resources across its plains and mountains, providing potential locations for direct heating and cooling systems. Yet, with current technology, Colorado's resource is unlikely to support economically viable geothermal power plants.

Electricity Generation Potential:
0 million MWh/yr.

Biomass

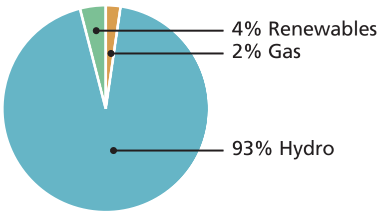


With significant agricultural operations, Colorado is a good candidate for increased use of biomass fuels, especially those that do not require large amounts of water to produce. The Colorado Office of Energy Management and Conservation has been working with Colorado Pork, LLC on a demonstration project to generate electricity using methane produced by hog farming operations.

Electricity Generation Potential:
4 million MWh/yr.

Idaho Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

Idaho's existing generation mix heavily favors hydroelectricity produced from dams along the state's many rivers. Non-hydro renewable sources, mostly biomass, make up 4% of the mix. Given the insignificant amount of development of other renewables – and the promising potential of geothermal and wind – Idaho has the opportunity to share in the benefits of a diverse, distributed clean energy supply, thereby reducing the burden on rivers and streams.

Renewable Energy
Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	0 MW
Solar (PV)	0.12 MW
Solar (Thermal)	0 MW
Geothermal	0 MW
Biomass	119.6 MW
Total	**120 MW**

[1]*Source: REPIS database*

Renewable Energy Policies

NM Net Metering
Maximum capacity set on a utility-by-utility basis: Avista Utilities – 25 kW; Idaho Power Company's policy is under revision.

GP Green Power Programs

$T Personal/Corporate Tax Incentives

$ Rebate, Grant or Low Interest Loan Programs

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

23 million MWh

Geothermal Heating in Boise

Idaho State Capitol Building

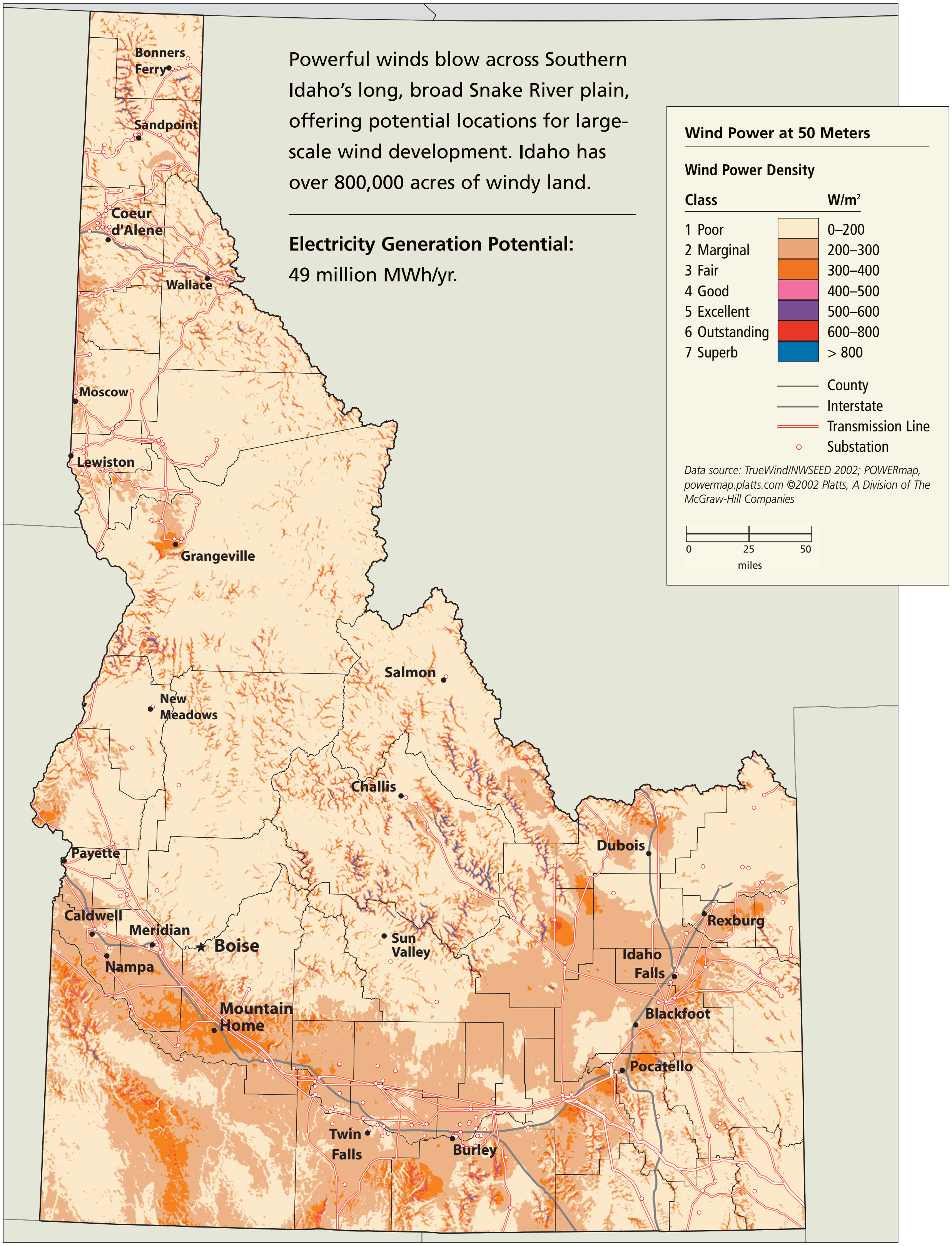
Photo: Diane M. Holt, IDWR

In 1892, the city of Boise led the West by creating the first modern heating system using direct-use geothermal energy. Low-temperature wells, found throughout Idaho, offer opportunities for direct heating and cooling through "district heating" systems that use hot water from geothermal wells to heat city water. The hot water is then piped to buildings in the city and run through heat exchangers to warm air for heating the buildings. District heating systems have been developed throughout the state and now constitute 102 MW of thermal geothermal energy. However, there are no facilities currently producing electricity from geothermal resources. Boise's Warm Springs district heating system has been joined by three other systems within the city – the Boise City System, the Veterans Administration Hospital System, and the Capitol Mall Complex System. The six-story Ada County building is the newest addition. These systems are providing clean and economical heat to 366 buildings – more than 4.4 million square feet of space (equivalent to heating 1,700 houses).

Wind

Powerful winds blow across Southern Idaho's long, broad Snake River plain, offering potential locations for large-scale wind development. Idaho has over 800,000 acres of windy land.

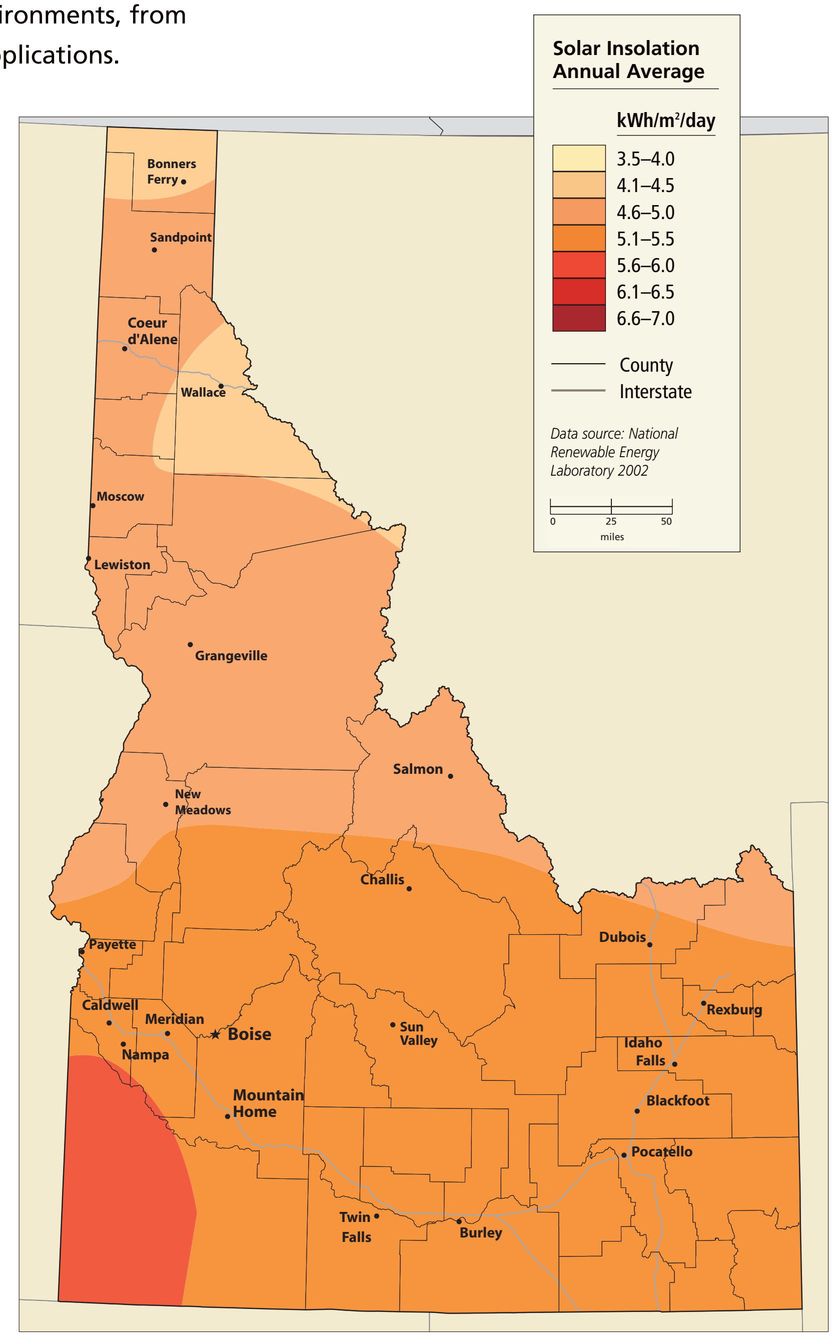
Electricity Generation Potential:
49 million MWh/yr.



Solar

Southern Idaho, including the state capitol of Boise, is home to a very good solar energy resource. Both active and passive solar technologies may be effectively used in a variety of environments, from urban rooftops to remote farm applications.

Electricity Generation Potential: 60 million MWh/yr.



Rural PV installation

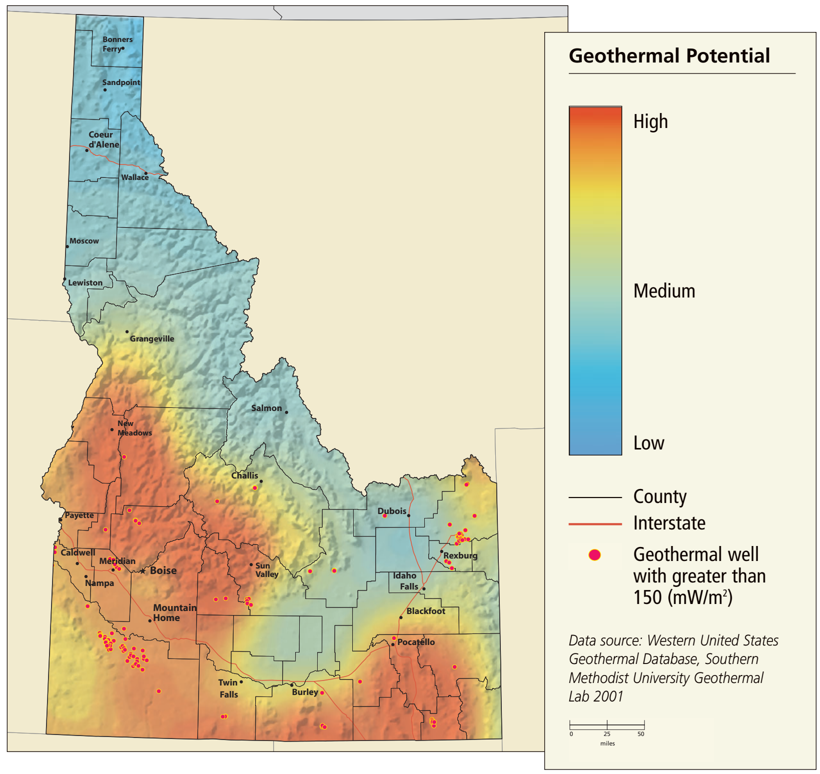
Backwoods Solar Electric Systems, outside of Sandpoint, Idaho, is miles from utility lines. They use off-grid renewable energy sources to power their home and business. The system includes photovoltaics, wind power and a backup generator creating 3 kW of power.

Photo: Backwoods Solar Electric Systems

Geothermal

Low-temperature geothermal sources provide heating to homes, municipal districts, swimming pools, fish farms and greenhouses throughout the state. High-temperature well sites spread across the southern half of the state offer the opportunity for electricity production.

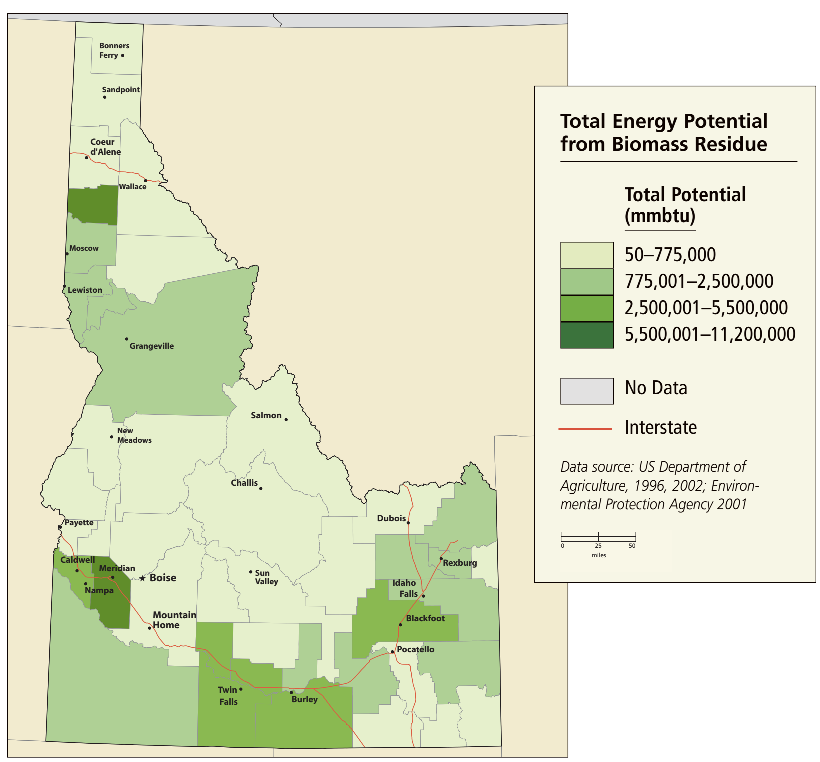
Electricity Generation Potential:
5 million MWh/yr.



Biomass

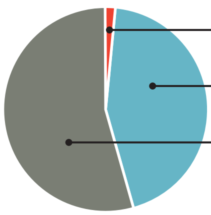
Compared to other states in the West, Idaho has a large amount of installed biomass capacity (120 MW or 4% of the state's energy mix).

Electricity Generation Potential:
9 million MWh/yr.



Montana Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

Montana generates a very small percentage of its electricity mix from renewables – almost all from biomass. However, eastern Montana offers several key locations for large-scale wind installations near the transmission grid. In fact, the wind resource alone could provide enough power for the entire state more than 70 times over.

Renewable Energy Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	0.24 MW
Solar (PV)	0.03 MW
Solar (Thermal)	0 MW
Geothermal	0 MW
Biomass	16.05 MW
Total	**16 MW**

[1]Source: REPIS database, plus known installations

Renewable Energy Policies

SBC System Benefits Charge
Approximately $15 million annually to renewables, efficiency, low-income energy assistance, renewables R&D.

NM Net Metering
Maximum capacity: 50 kW

GP Green Power Programs
Mandatory utility green power option

$T Personal/Corporate Tax Incentives

$P Property Tax Exemption

$ Rebate, Grant or Loan Program

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

13 million MWh

Wind-Powered Irrigation

Grid-Connected Small Wind Turbine

Photo: Warren Gretz, NREL

Montana is blessed with an exceptional wind power resource that will sustain many small- and large-scale wind turbine installations on farms, ranches and tribal lands. Where the transmission grid is accessible, small-scale wind turbines can connect directly to existing power lines and provide economic benefits for rural landowners by allowing them to sell their extra power back to the utility (net metering). A 10 kW wind turbine placed in a windy location will produce an average of 1200 to 1800 kWh per month, enough to significantly offset the electricity load of a farm or ranch. Net metering allows individual power producers to draw energy from the grid when they need it, and sell excess power back to the grid when they aren't using it. This is useful for irrigators whose power needs are greatest during the summer growing season, while most of their wind electricity is generated in the winter. An Anemometer Loan Program spearheaded by the National Center for Appropriate Technology (NCAT) allows rural landowners to measure their wind resource, helping to determine the costs and benefits of installing a wind turbine.

Wind

Western Montana's breezy foothills and Rocky Mountains, along with eastern Montana's almost uniformly outstanding wind resource, offer abundant opportunities for small-scale and commercial-scale wind development. Montana has the best wind resource of the eleven Western states, with over 17 million acres of windy land.

Electricity Generation Potential: 1,020 million MWh/yr.

Wind Power at 50 Meters

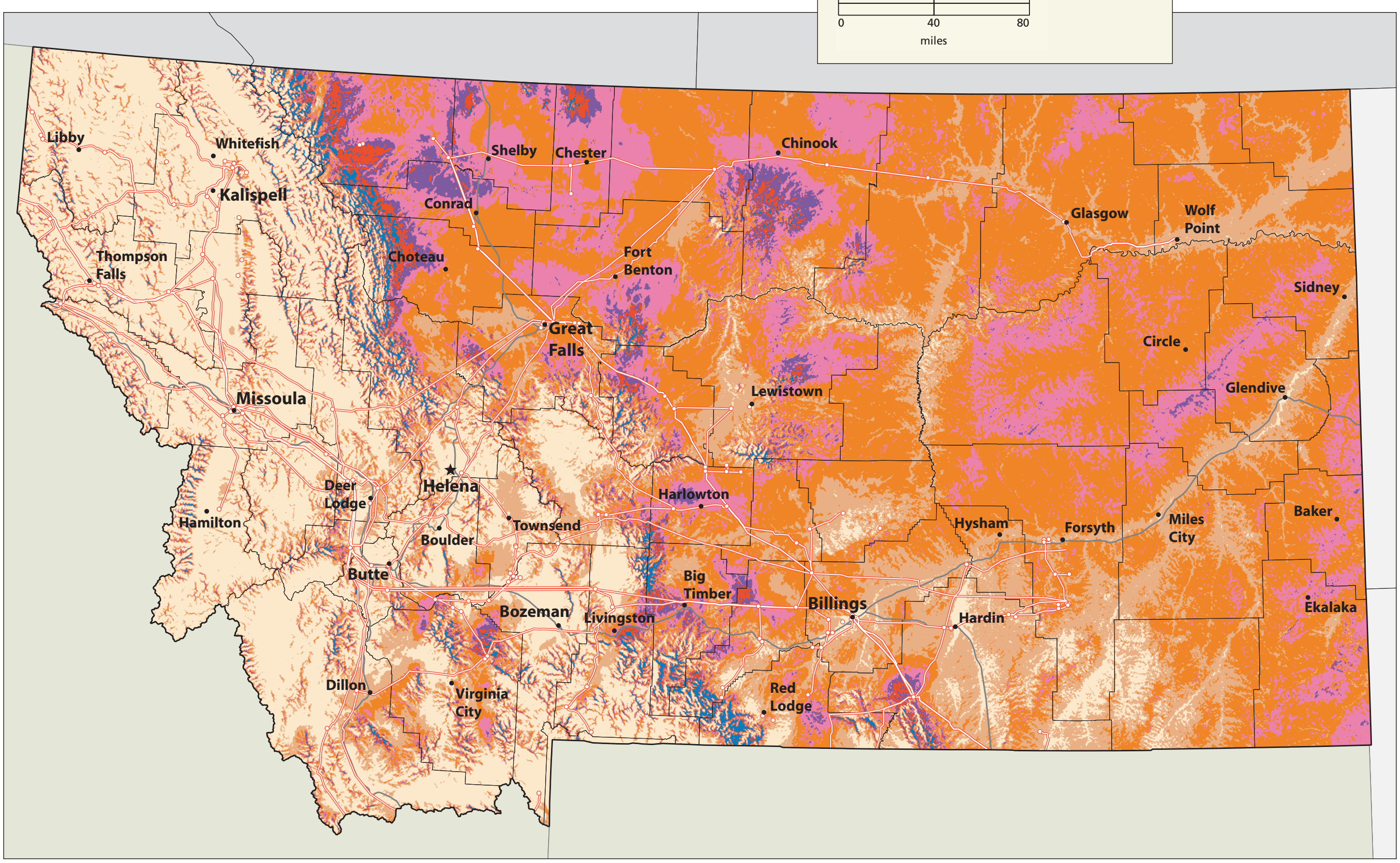
Wind Power Density

Class	W/m²
1 Poor	0–200
2 Marginal	200–300
3 Fair	300–400
4 Good	400–500
5 Excellent	500–600
6 Outstanding	600–800
7 Superb	> 800

County
Interstate
Transmission Line
Substation

Data source: TrueWind/NWSEED 2002; POWERmap, powermap.platts.com ©2002 Platts, A Division of The McGraw-Hill Companies

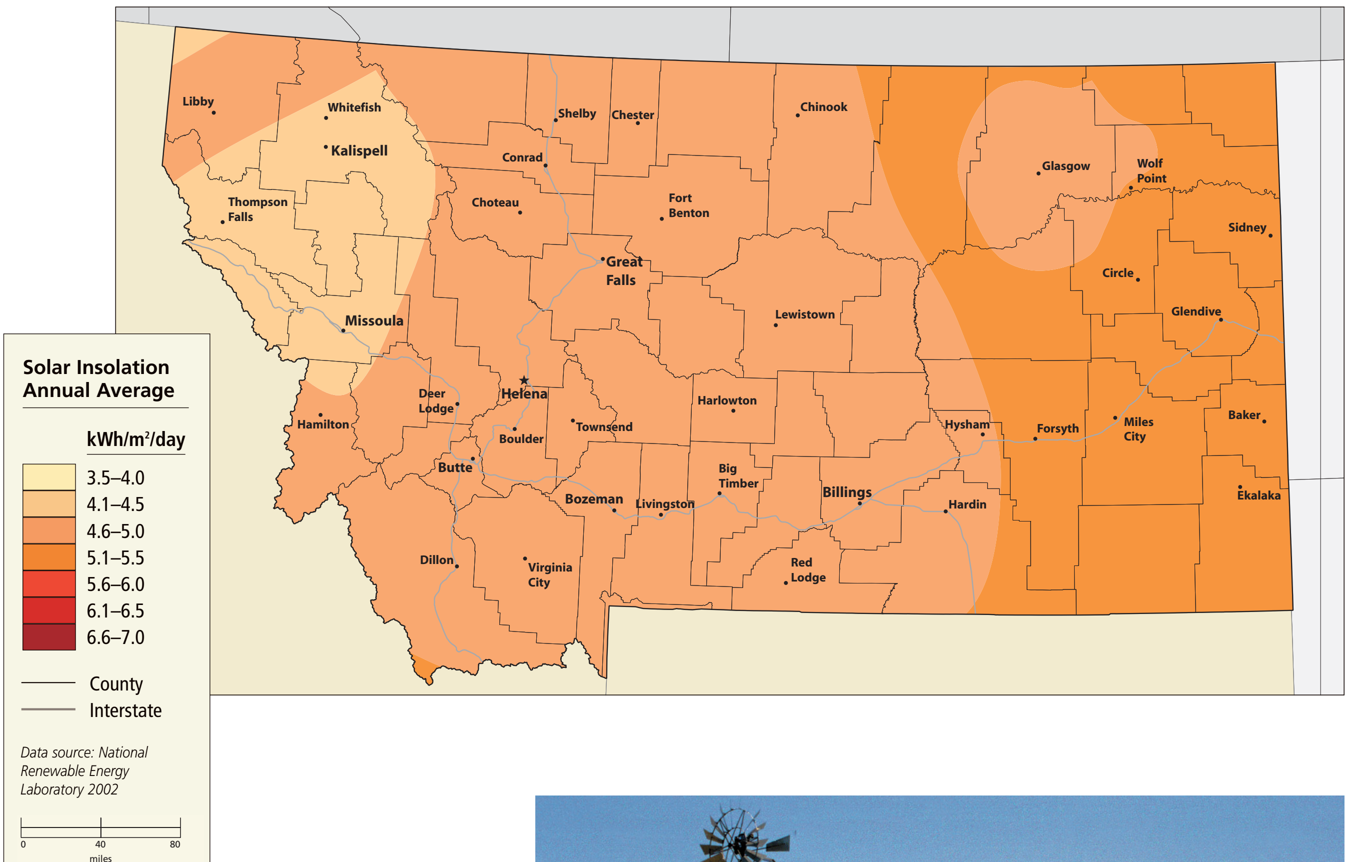
0 40 80
miles



Solar

Solar energy applications have real potential throughout the state of Montana. The Sun4Schools program, funded through a system benefits charge added to all electric customers' bills, has built PV systems on twelve schools that offset electricity costs and provide invaluable lessons to the students. The system benefits charge generates approximately $15 million each year for renewables, efficiency and low-income energy assistance.

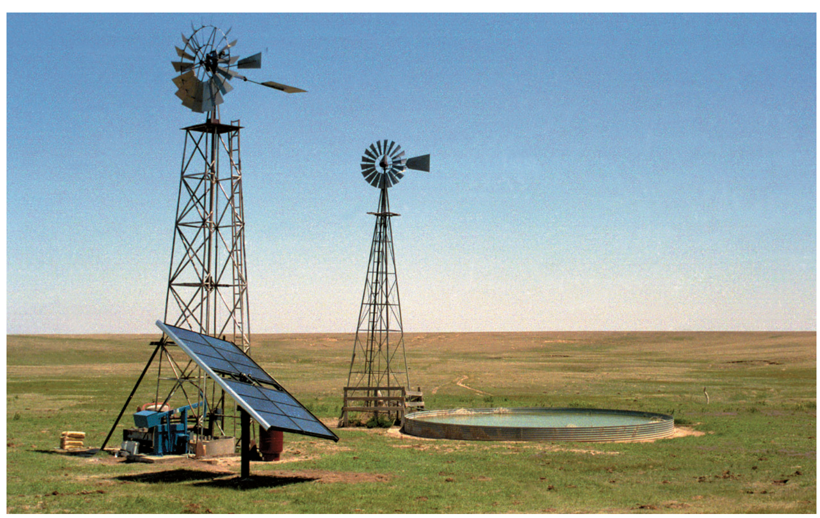
Electricity Generation Potential: 101 million MWh/yr.



Solar and Wind for Agriculture

New technology meets old in this photo, where photovoltaics complement traditional wind turbines at a remote water pumping station. The combination of these two technologies offers a more reliable power source for off-grid applications.

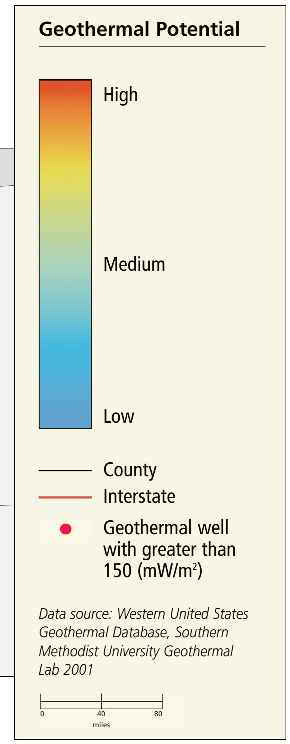
Photo: NEOS Corporation

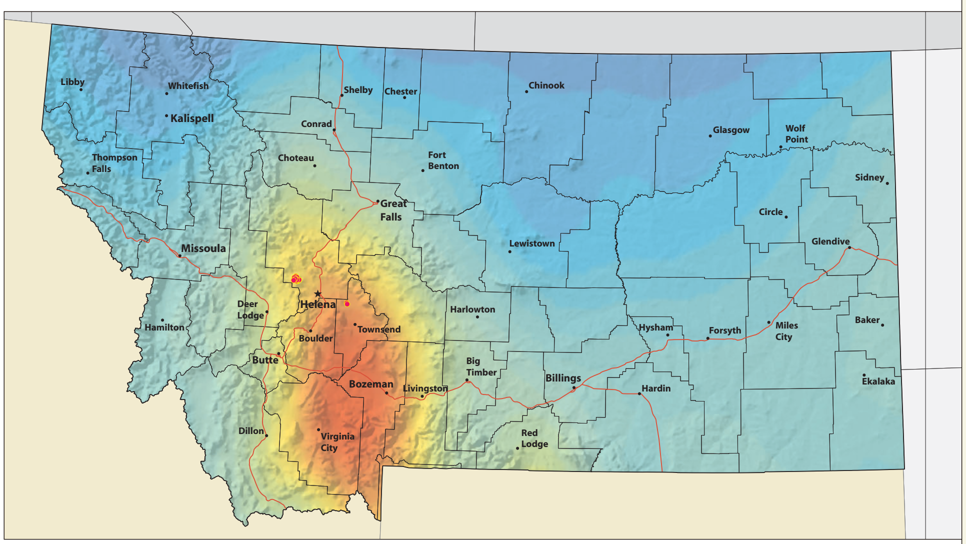


Geothermal

For Yellowstone National Park, a national treasure on Montana's border with Wyoming, geothermal activity at Old Faithful means all-natural entertainment for millions of tourists. For Montana residents, areas northwest of Yellowstone provide excellent opportunities for developing geothermal sites without harming the environment.

Electricity Generation Potential: N/A

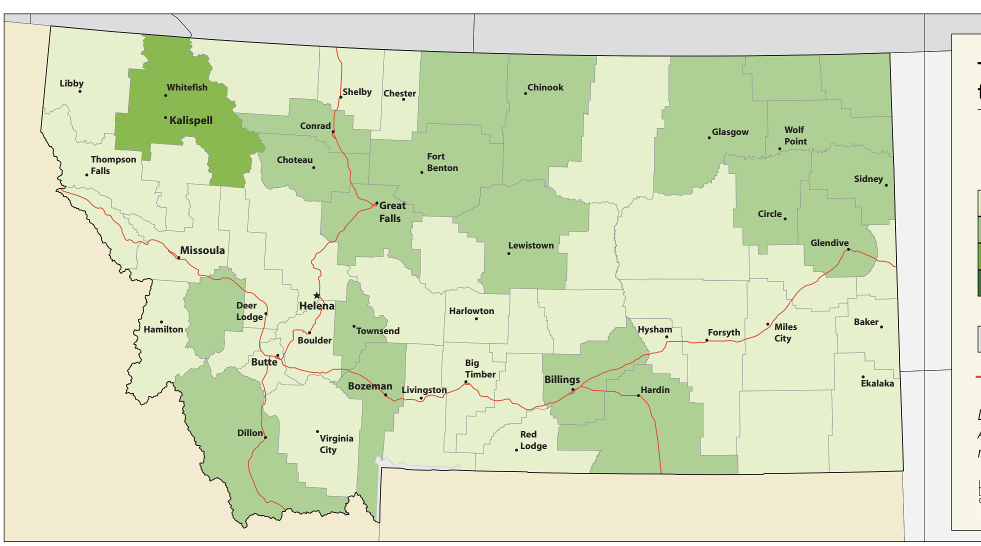


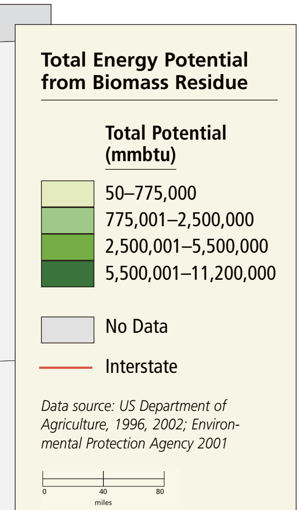


Biomass

Statewide farming and ranching operations could provide fuel for electricity generating plants. Montana currently has 16 MW of biomass, primarily from forest product residues.

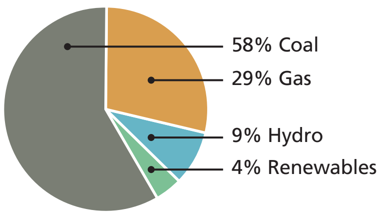
Electricity Generation Potential: 6 million MWh/yr.





Nevada Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

Nevada is one of the most versatile states for renewable energy, with excellent sites for developing all four renewable resources. The state ranks 4th in the region for installed capacity of renewable energy, with 4% of its electricity generation coming from geothermal facilities. In 2001 Nevada made a significant commitment to developing renewable resources by passing the country's largest renewable portfolio standard – 15% of the state's electricity will be generated from renewables by 2013.

Renewable Energy Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	0 MW
Solar (PV)	0.08 MW
Solar (Thermal)	0 MW
Geothermal	237.8 MW
Biomass	0 MW
Total	**238 MW**

[1]*Source: REPIS database, plus known installations*

Renewable Energy Policies

RPS Renewable Portfolio Standard
5% in 2003, 15% in 2013. Solar minimum is 5% of renewables.

NM Net Metering
Maximum capacity – 10 kW

GP Green Power Programs

$P Property Tax Exemption

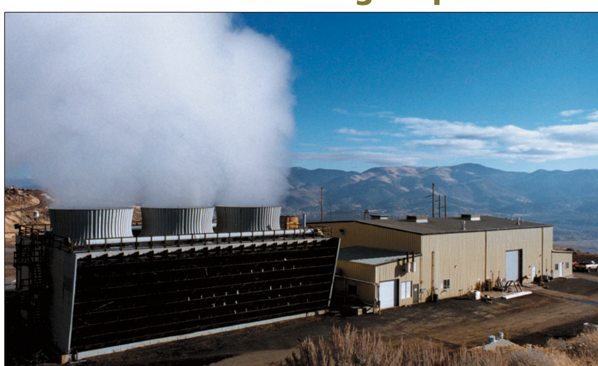
$ Rebate, Grant or Loan Program

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

26 million MWh

Geothermal Energy for Food Processing Operations



Steamboat Hills Geothermal Power Plant

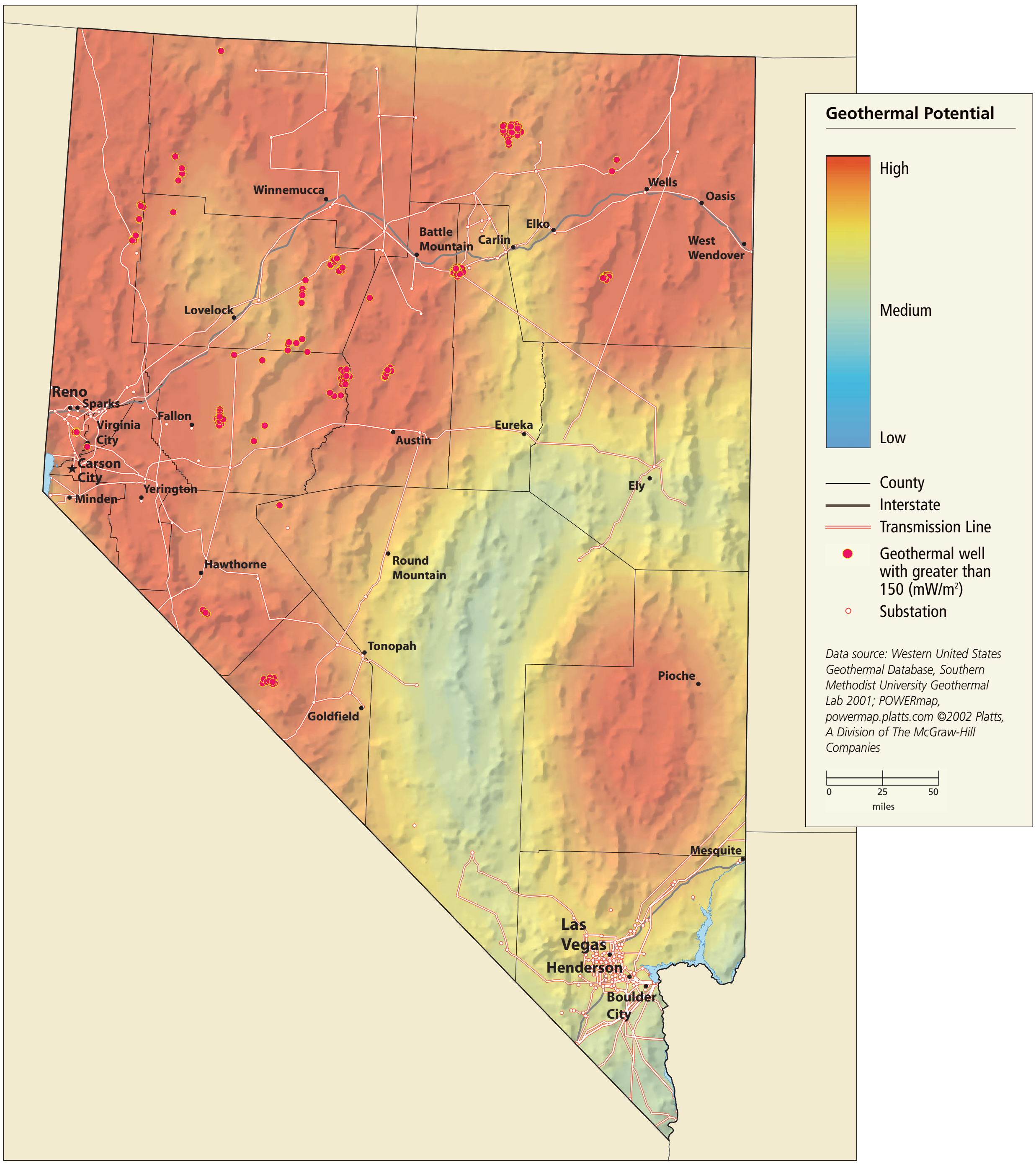
Photo: Joel Renner, INEEL

Nevada has the greatest geothermal resource of any state in the country. The state has tapped into these extensive resources for direct heating and cooling and for electricity production. There are several food processing plants that use geothermal power for direct heat and electricity production. Gilroy Foods (in Fernley, NV) and Empire Foods (in the San Emidio Valley) both use geothermal energy for their garlic and onion dehydration plants. According to the US Department of Energy, the state received more than $2 million in royalties from the geothermal industry in 1999. Nevada is also home to several geothermal research facilities at universities, federal and state agencies and other organizations.

Geothermal

Nevada's first geothermal power plant was developed in 1984. The state's installed capacity has since grown to nearly 238 MW. Passage of the state's renewable portfolio standard (RPS) has given geothermal an even bigger boost, since the resource is expected to play an essential role in meeting the goal set by the RPS to produce 15% of electricity from renewables by 2013.

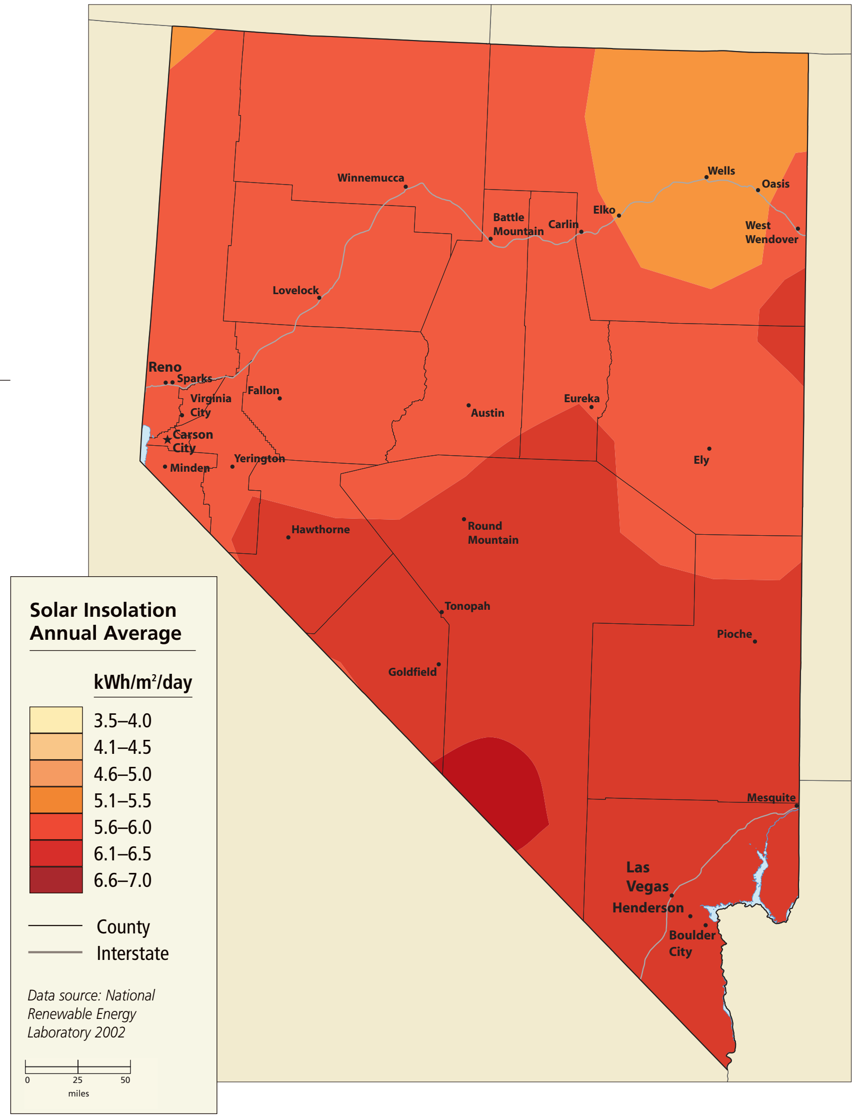
Electricity Generation Potential: 20 million MWh/yr.



Solar

Las Vegas, the country's fastest growing city for at least a decade, sits in an ideal solar resource in southern Nevada. Small-scale PV projects offer a tangible opportunity for residents and businesses – including casinos – to offset their energy bills.

Electricity Generation Potential:
93 million MWh/yr.

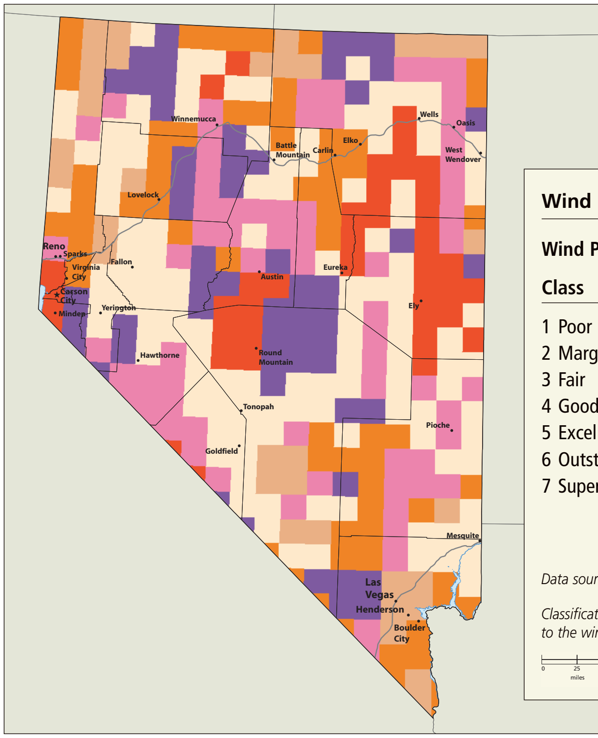


PV Lighting

PV provides power for all-night illumination of bus stops on the Strip in downtown Las Vegas.

Photo: John Thornton

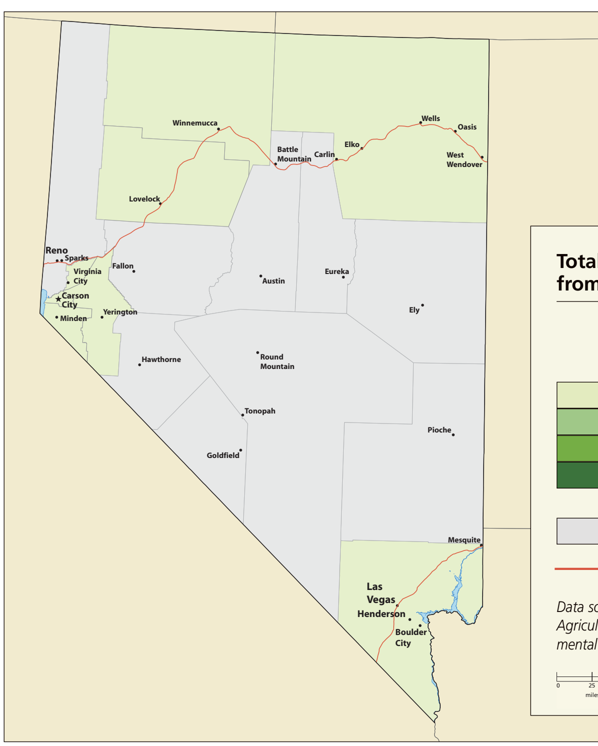
Wind



While Nevada has yet to tap into its favorable wind resource, several new projects are planned. One facility proposed for the former Nevada Test Site could consist of up to 550 wind turbines. Nevada's windy lands suitable for development total nearly 900,000 acres.

Electricity Generation Potential: 55 million MWh/yr.

Biomass

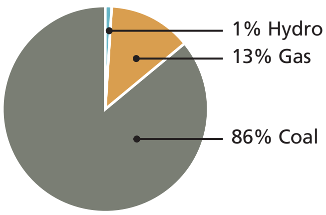


An arid state, Nevada does not produce a high volume of agricultural crops or residues suitable for bioenergy.

Electricity Generation Potential: 1 million MWh/yr.

New Mexico Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

New Mexico has abundant renewable resources – especially wind, solar and geothermal. However, the state currently produces less than 1% of its energy from renewable resources and ranks last among the eleven Western states in total installed renewable energy capacity (less than 4 MW).

Renewable Energy Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	1.32 MW
Solar (PV)	0.11 MW
Solar (Thermal)	0 MW
Geothermal	0 MW
Biomass	2.2 MW
Total	**3 MW**

[1]*Source: REPIS database, plus known installations*

Renewable Energy Policies

SBC System Benefits Charge
Tied to restructuring, to begin 2007

RPS Renewable Portfolio Standard
Tied to restructuring, to begin 2007

NM Net Metering
Maximum capacity – 10 kW

GP Green Power Programs

$ State-Level Production Tax Credit

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

18 million MWh

Producing Electricity from Wastewater

Southside Water Reclamation Plant's High Speed Centrifuge

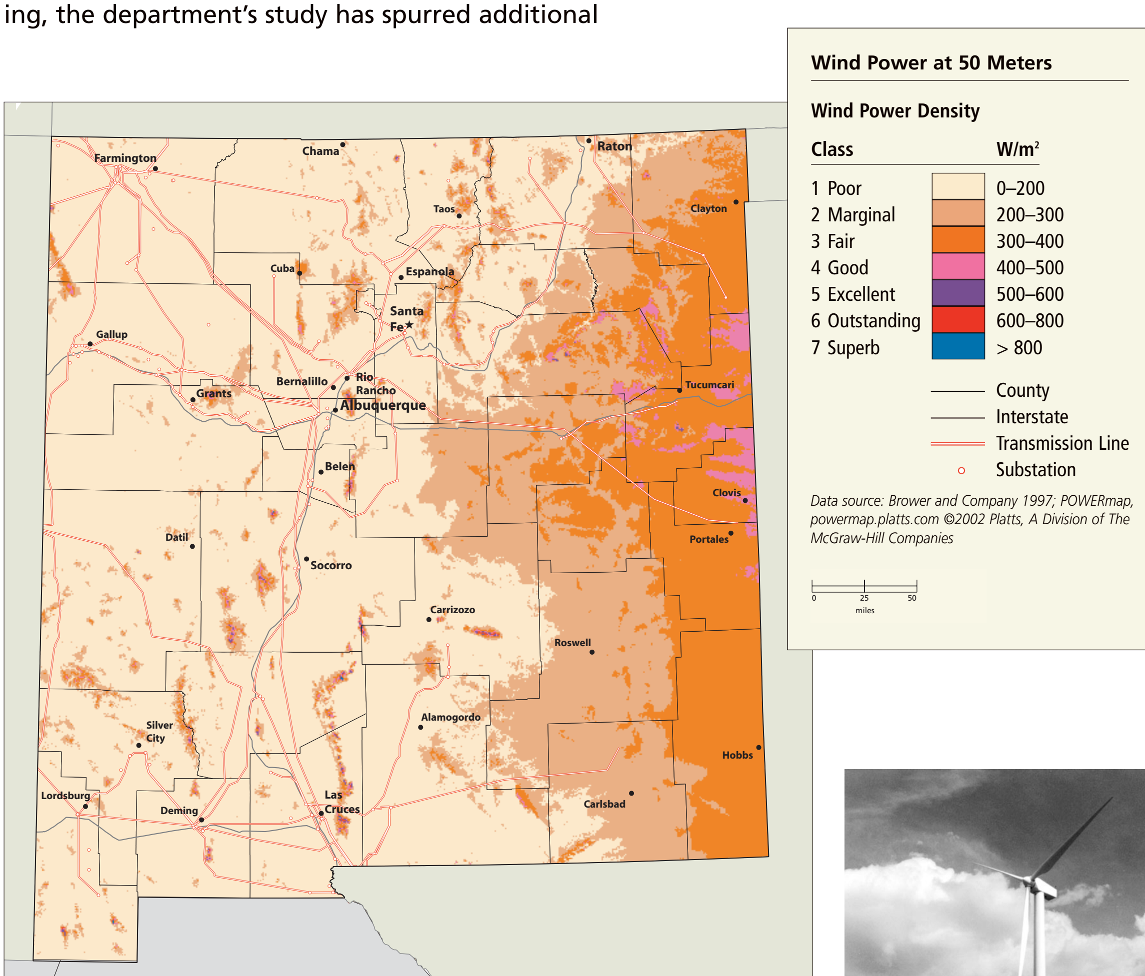
Photo: Kay L. Lang, City of Albuquerque

The City of Albuquerque's Southside Water Reclamation Plant treats wastewater from virtually all homes, schools and businesses within the city limits – approximately 52 million gallons of wastewater per day. The city plant uses methane produced from the wastewater treatment process to generate electricity and hot water for the facility. Using gas produced during the water treatment process has double environmental benefits: (1) it reduces the direct emissions of greenhouse gases, and (2) the electricity generated reduces the facility's use of electricity produced with fossil fuels, thereby reducing additional air emissions. This 2.2 MW "cogeneration" plant currently produces about half of the power used by the wastewater treatment facility – saving the city about $70,000 per month in utility bills. It is currently the only biomass facility in the state.

Wind

New Mexico has abundant wind power resources – primarily on the eastern plains. In addition to data shown here, the New Mexico Energy, Minerals and Natural Resources Department collected wind data at six promising sites for wind development. While only one utility-scale turbine is currently operating, the department's study has spurred additional interest from commercial developers. New Mexico is estimated to have over 1 million acres of windy land suitable for commercial development.

Electricity Generation Potential: 56 million MWh/yr.

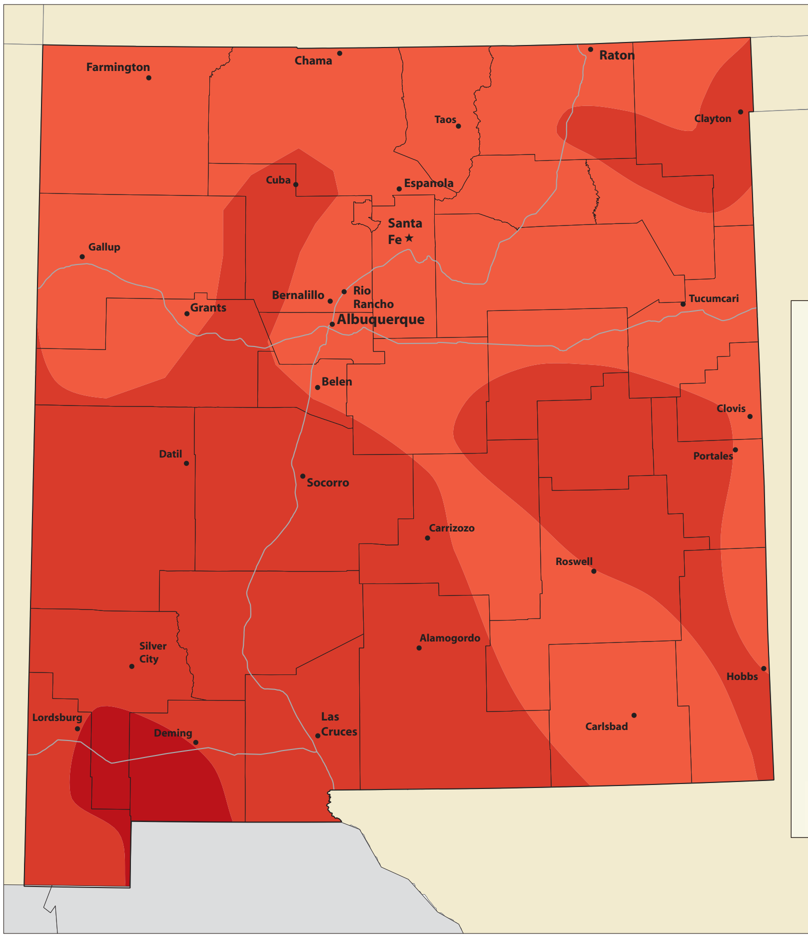


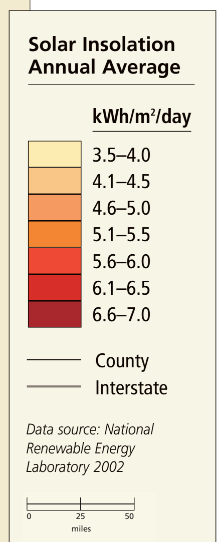
New Mexico's Clovis Wind Turbine

Erected in 1999, the Clovis wind turbine is currently New Mexico's only utility-scale turbine. Output from the turbine – located near the state's eastern border – is sold to customers of Southwestern Public Service Company's *Windsource* program.

Photo: Bill Crenshaw, Xcel Energy

Solar





Like the other southwestern states, New Mexico has an outstanding solar resource. There are at least 80 kW of PV installed in both grid-tied and off-grid applications.

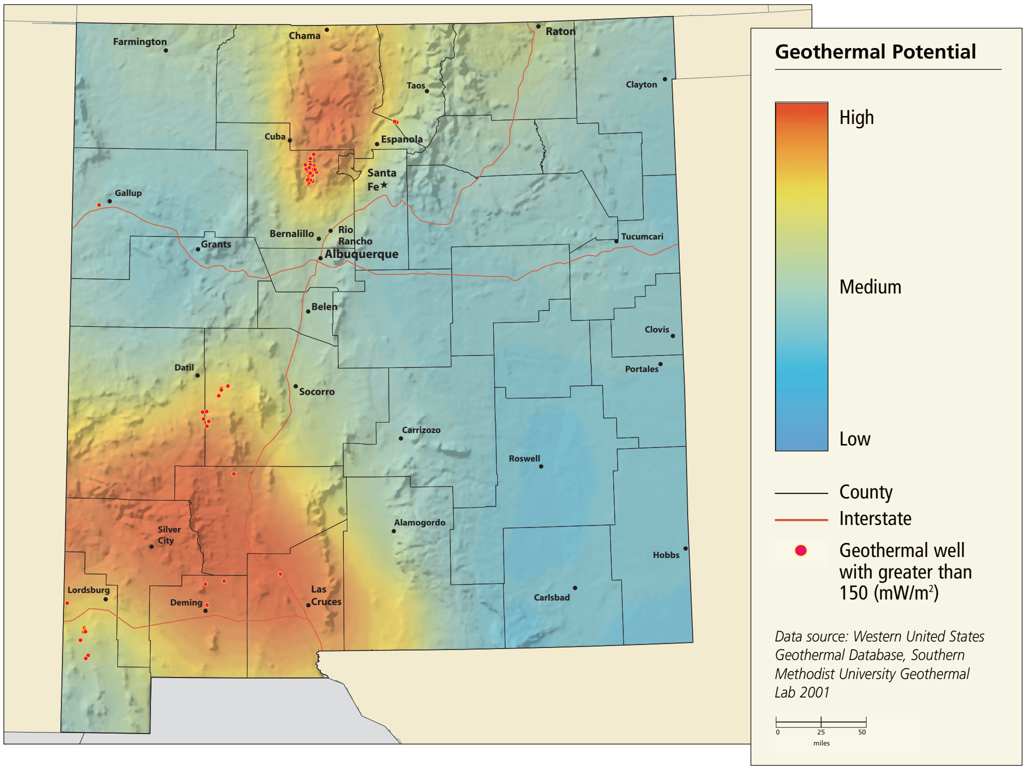
Electricity Generation Potential: 104 million MWh/yr.

Indian Pueblo Cultural Center in Albuquerque

This PV carport represents the largest Native American PV installation in the United States. The system delivers about 23 Megawatt hours per year to the local utility grid (Public Service Company of New Mexico) and was built by Diversified Systems Manufacturing, a Native American-owned and -operated PV development company.

Photo: Sandia National Laboratories

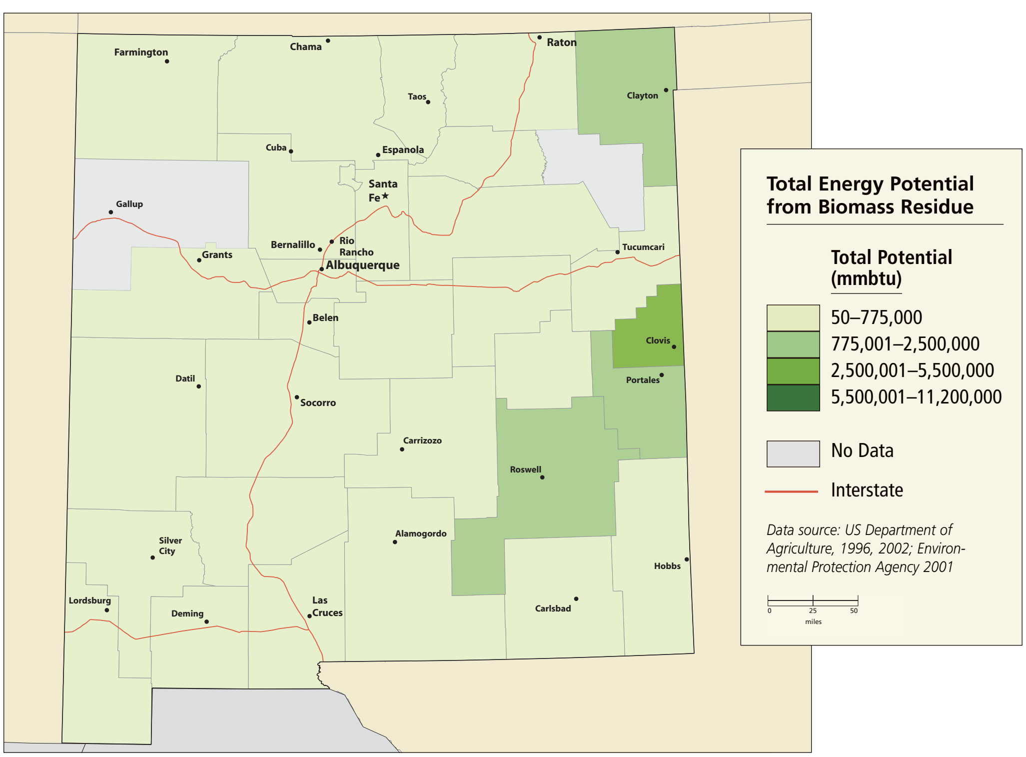
Geothermal



New Mexico has very good geothermal resources, particularly in the southwest and north central parts of the state. There are currently no utility-scale installations, but there are numerous direct-use applications in homes and businesses, including greenhouses and fish farms.

Electricity Generation Potential:
3 million MWh/yr.

Biomass

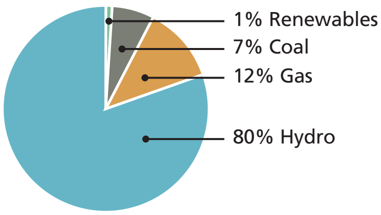


An arid state, New Mexico has less potential for agricultural or forest wastes for biomass electricity production than many other Western states.

Electricity Generation Potential:
0 million MWh/yr.

Oregon Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

Oregon ranks third in the region for installed capacity of renewable energy, behind California and Washington. However, renewables account for less than 1% of the state's total energy mix. Renewable energy development has picked up in recent years with the construction of four commercial wind farms and the expansion of biomass energy production.

Renewable Energy Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	157.52 MW
Solar (PV)	0.05 MW
Solar (Thermal)	0 MW
Geothermal	0 MW
Biomass	145 MW
Total	**303 MW**

[1]*Source: REPIS database, plus known installations*

Renewable Energy Policies

SBC System Benefits Charge
$8.7 million raised annually for renewables

NM Net Metering
Maximum capacity – 25 kW

GP Green Power Programs

$T Personal/Corporate Tax Incentives

$P Property Tax Exemption

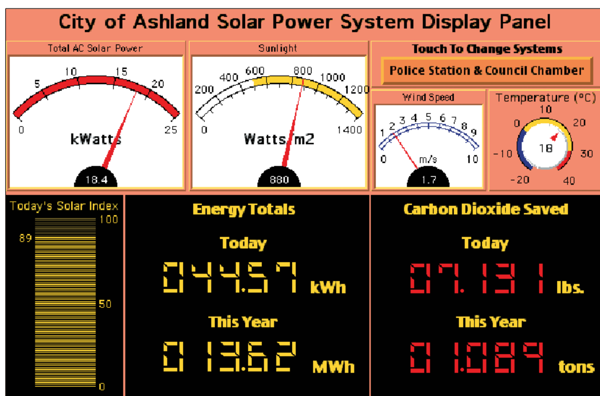
$ Rebate, Grant or Loan Program

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

48 million MWh

Solar Ashland



Ashland's Real-Time Solar Display

Source: Applied Power Corporation

The City of Ashland is home to the famous Oregon Shakespeare Festival, which attracts over 110,000 people each year. Visitors not only enjoy theater productions but also have the chance to view the newest addition to the Solar Ashland program: a 5 kW solar PV array. Solar Ashland is a solar demonstration program funded by the Bonneville Environmental Foundation. The first phase of this project generates 30 kW of electricity at highly visible locations, including the Shakespeare Festival, police station, City Council chambers, and Southern Oregon University. The city's Web site hosts a real-time solar index (see image at left), where residents can keep track not only of the electricity generated by the solar arrays but also how much air pollution the systems have prevented.

Wind

Oregon electricity consumers served by Portland General Electric, Eugene Water and Electric Board, and Pacific Power have the option to buy blocks of wind-generated electricity through utility green pricing programs. Revenue from these programs funds new "home-grown" green power projects throughout the state of Oregon. Oregon has over 1 million acres of windy land, including the region bordering Washington.

Electricity Generation Potential: 70 million MWh/yr.

Wind Power at 50 Meters

Wind Power Density

Class	W/m²
1 Poor	0–200
2 Marginal	200–300
3 Fair	300–400
4 Good	400–500
5 Excellent	500–600
6 Outstanding	600–800
7 Superb	> 800

Data Withheld

County

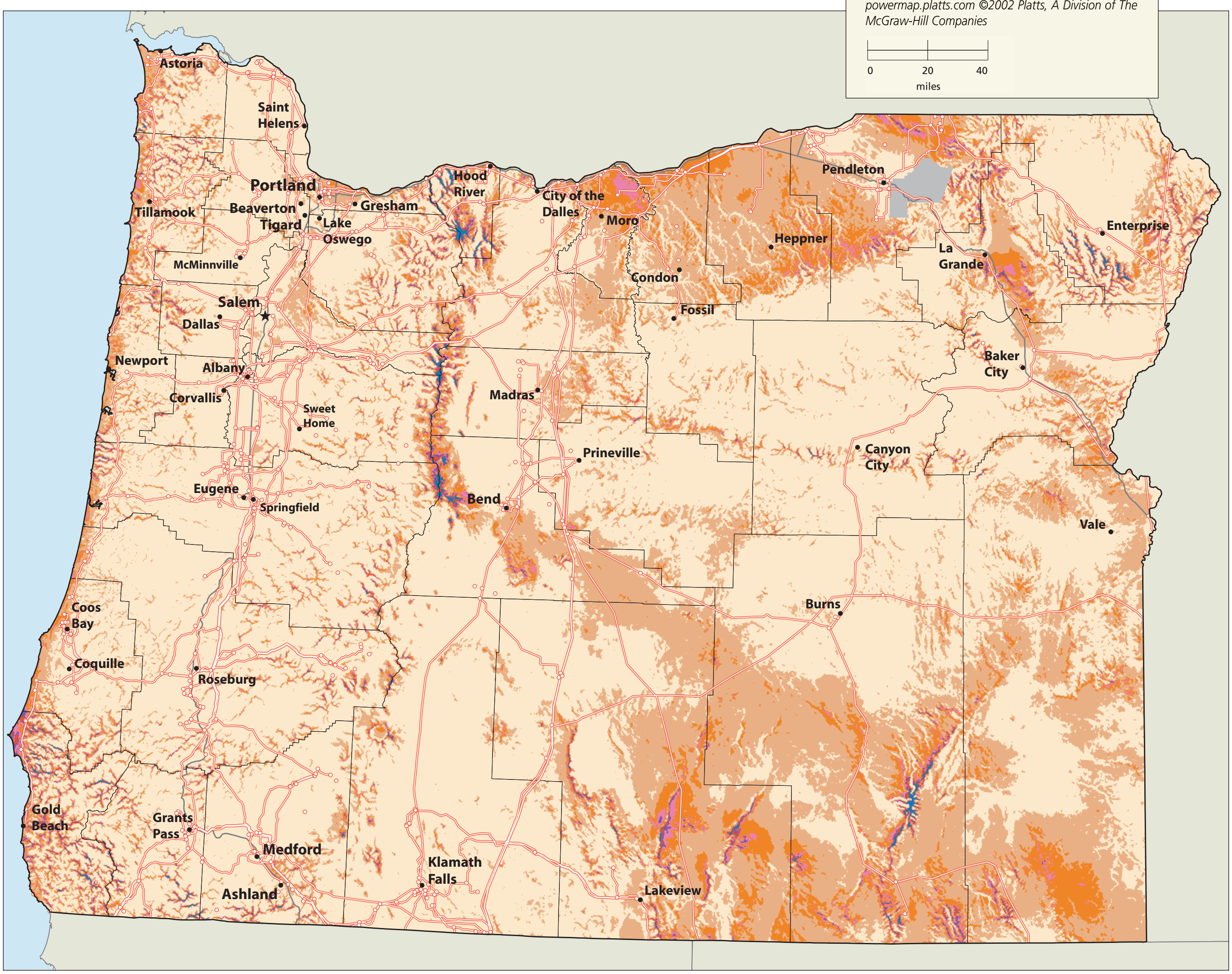
Interstate

Transmission Line

Substation

Data source: TrueWind/NWSEED 2002; POWERmap, powermap.platts.com ©2002 Platts, A Division of The McGraw-Hill Companies

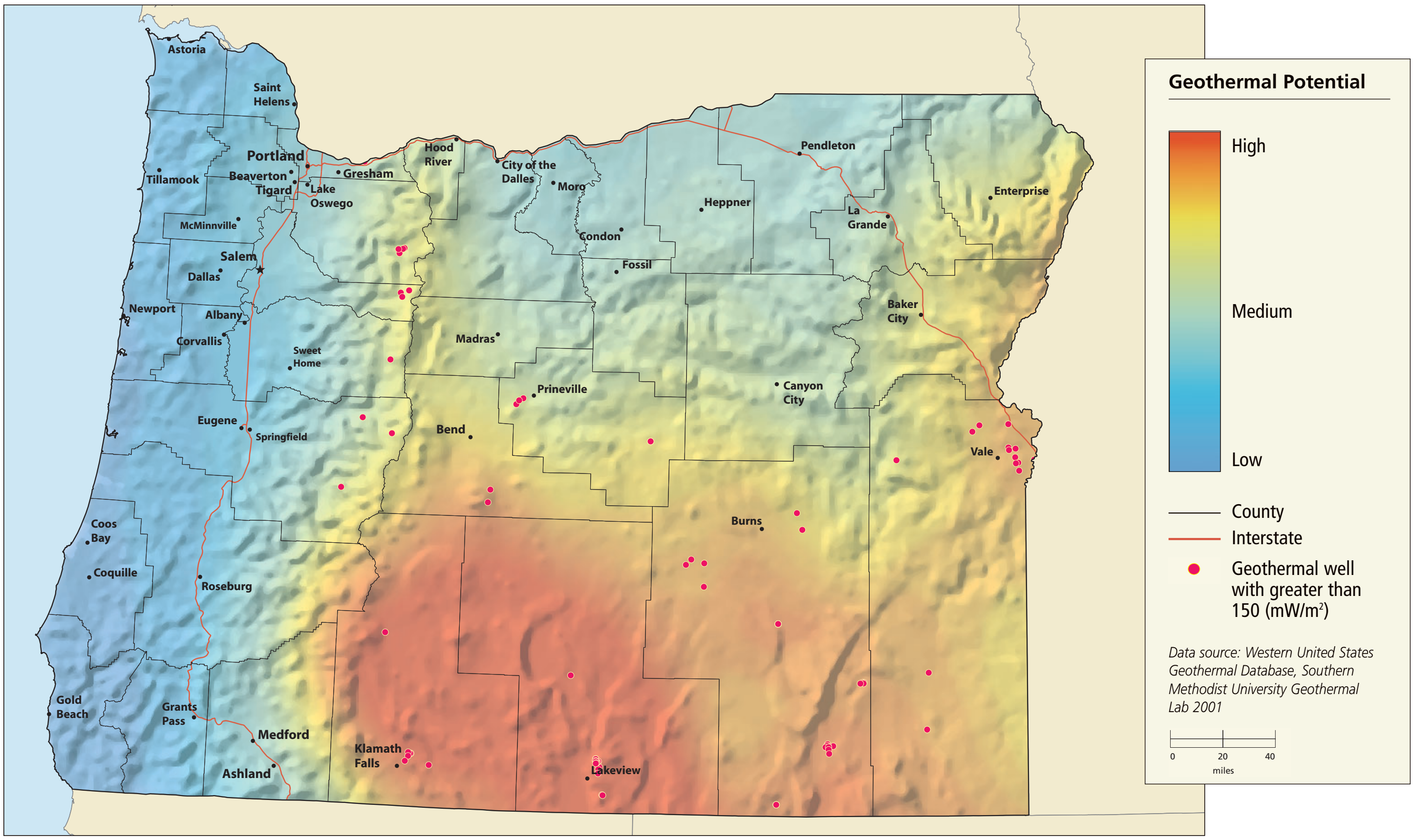
0 20 40
miles



Geothermal

Oregon has an outstanding geothermal resource, ideal for individual home heating, district heating and commercial-scale electricity production. For example, the city of Klamath Falls has used geothermal power to supply its district heating system since 1981.

Electricity Generation Potential: 17 million MWh/yr.



Oregon Institute of Technology Campus

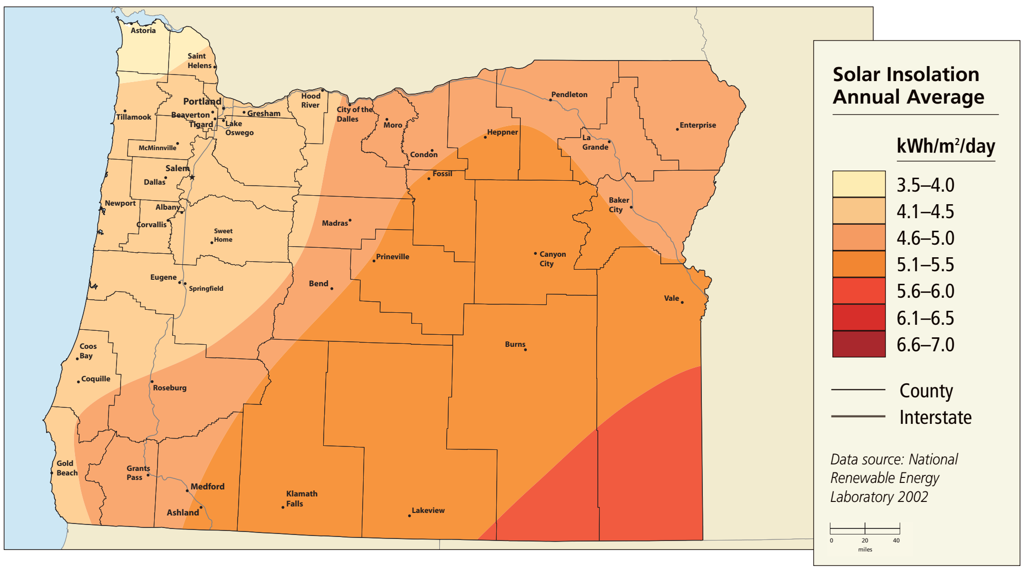
The Oregon Institute of Technology has been using a geothermal district heating system since 1964. Today, the system heats eleven buildings (600,000 square feet), provides domestic hot water, melts snow on 2,300 square feet of sidewalk and even cools five buildings during the summer. The district heating system saves around $225,000 each year.

Photo: Mary Smothers, Oregon Institute of Technology

Solar

Increased citizen interest in solar energy has resulted in several high-profile urban PV projects in the populous Willamette Valley in northwestern Oregon. The state's best solar resource is found in the southeast, where solar-powered homes and agricultural operations show great promise, especially considering Oregon's array of tax incentives for residents and businesses.

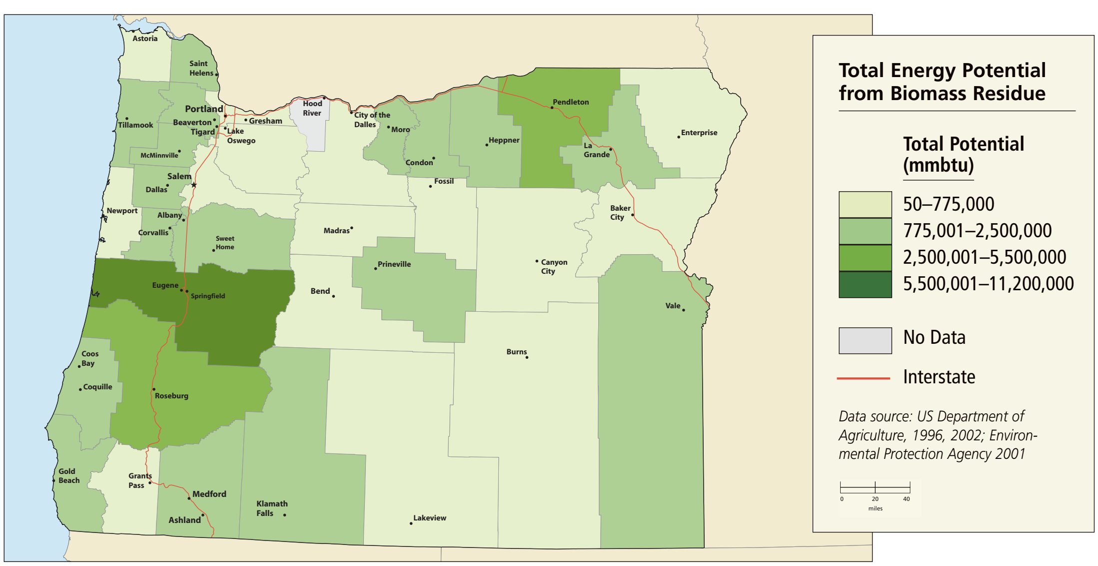
Electricity Generation Potential: 68 million MWh/yr.



Biomass

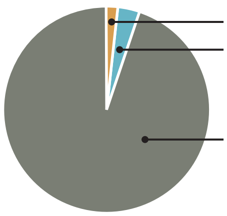
Oregon generates nearly 150 MW of electricity from biomass, the third largest capacity in the region behind California and Washington. Wood residues, agricultural crop residues and landfill gas could provide the state with additional clean power generation.

Electricity Generation Potential: 10 million MWh/yr.



Utah Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

Utah is known for spectacular scenery, but the state is also home to plentiful renewable resources. This is one of the few states in the region to have developed geothermal power plants, a total of 39 MW.

Renewable Energy Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	0.24 MW
Solar (PV)	0 MW
Solar (Thermal)	0 MW
Geothermal	39.3 MW
Biomass	4 MW
Total	**44 MW**

[1]Source: REPIS database, plus known installations

Renewable Energy Policies

NM Net Metering
Maximum capacity – 25 kW

GP Green Power Programs

$T Personal/Corporate Tax Incentives

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

22 million MWh

Zion National Park Visitor Center

Zion National Park's Visitor Center

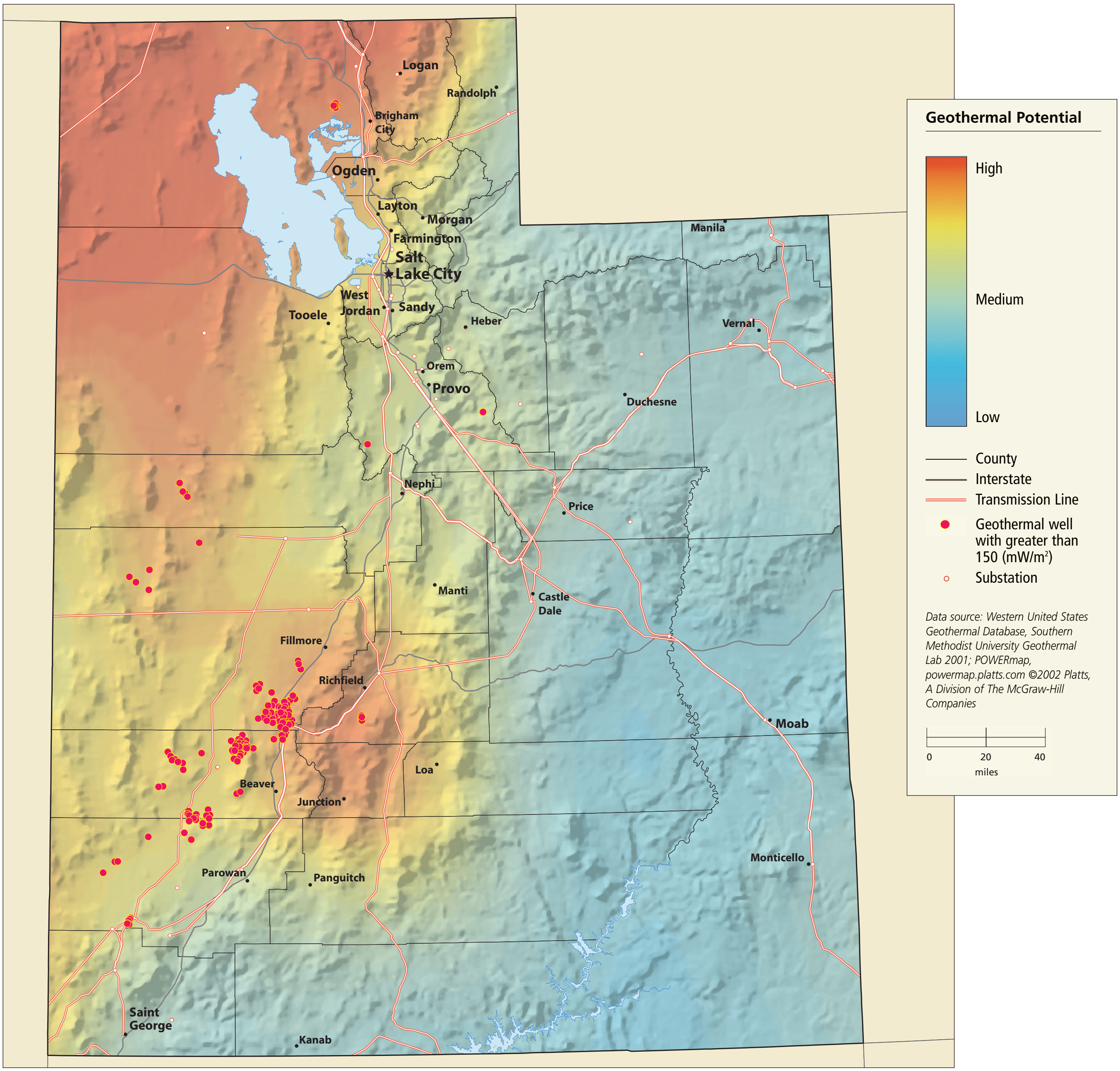
Photo: Thomas Wood

National parks serve as wonderful natural classrooms. At Utah's Zion National Park, nearly 2.5 million visitors per year learn about the area's natural history and cultural significance. Since completion of a new visitor center in 2000, visitors to the park have also been able to learn about energy efficiency, renewable energy and sustainable building design. The visitor center features a 7.2 kW photovoltaic system that provides about 10% of the building's energy use. Other features include passive solar design, high insulation levels, a 1,040 sq. ft. Trombe wall, daylighting and energy-efficient landscaping. As a result of these features, the visitor center is about 70% more energy-efficient than a comparably sized building.

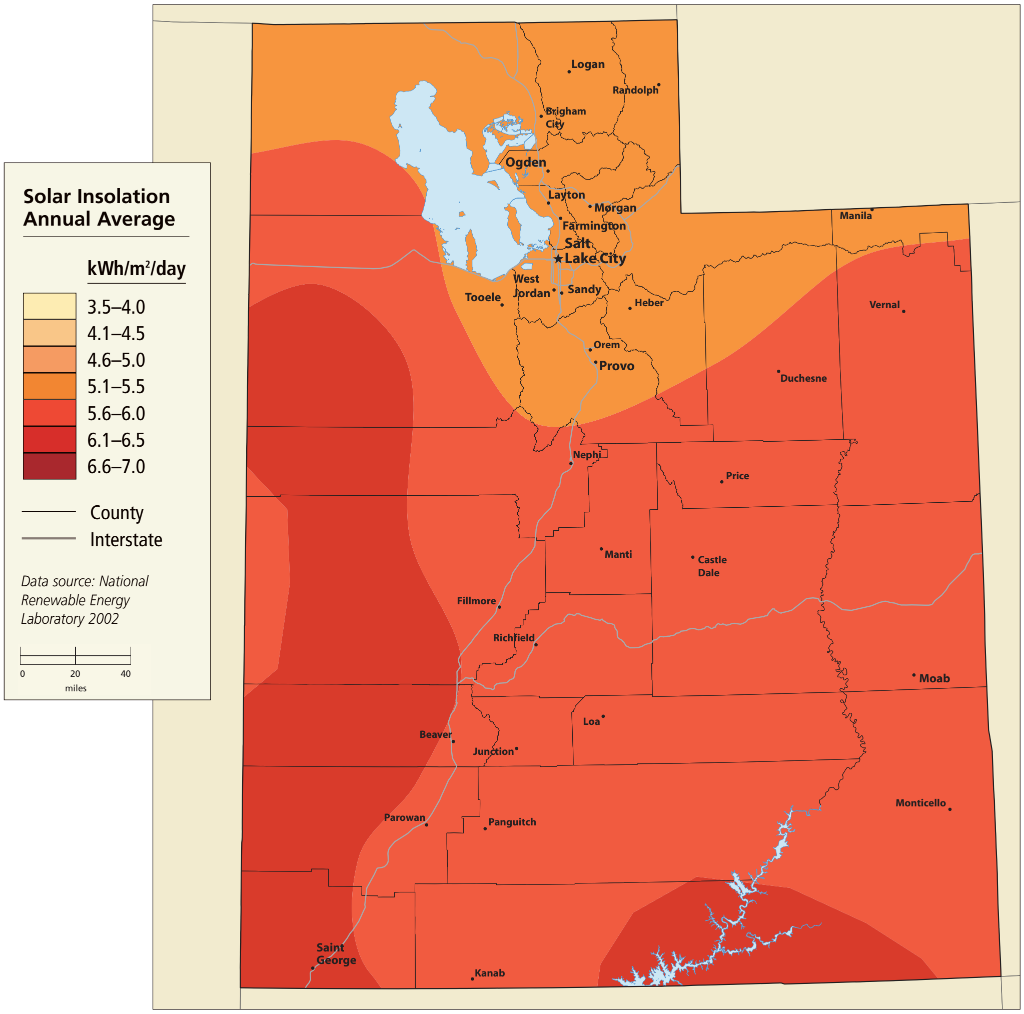
Geothermal

Most of Utah's current renewable energy production comes from geothermal. The resource is plentiful in the middle and northwest portions of the state, although a lack of transmission capacity may hinder electricity development in the northwest corner. However, geothermal presents an opportunity for direct heating and cooling in this part of the state.

Electricity Generation Potential: 9 million MWh/yr.



Solar



The southern half of Utah is home to excellent solar resources. The state has made attempts to boost solar development by adopting policies such as: personal and corporate tax credits for customers who install renewable energy systems, including photovoltaics. A solar access law allows landowners to apply a "solar easement" to their property, allowing them to protect and maintain proper access to sunlight for installed systems.

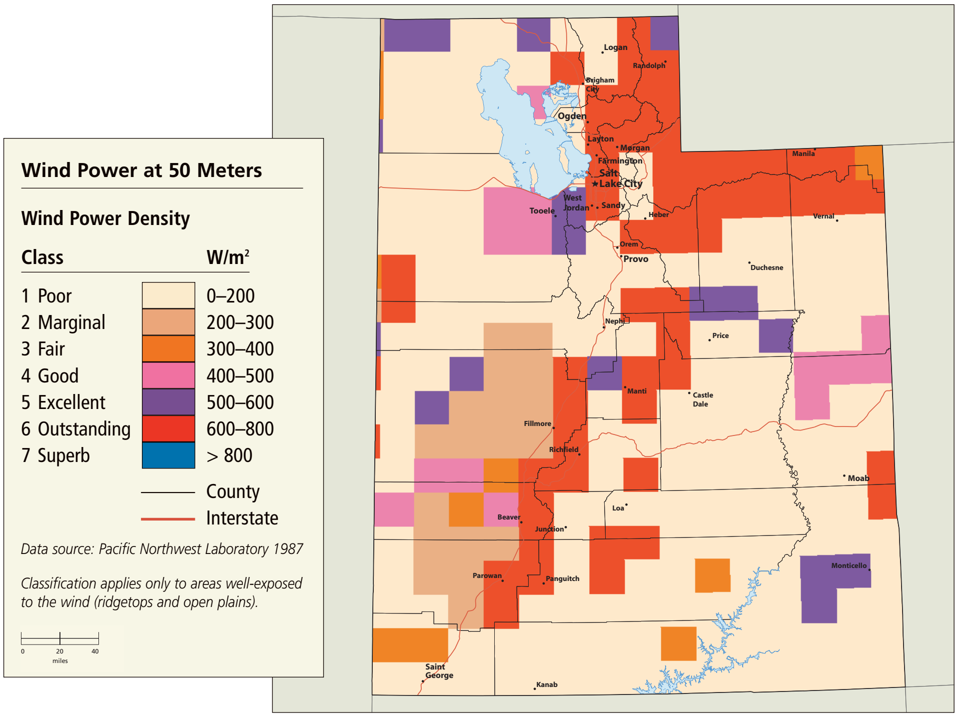
Electricity Generation Potential: 69 million MWh/yr.

Dangling Rope Marina

The Dangling Rope Marina in Utah's Glen Canyon National Recreation Area installed this 115 kW PV system in order to eliminate the use of more than 65,000 gallons of diesel fuel for generators every year.

Photo: Warren Gretz, NREL

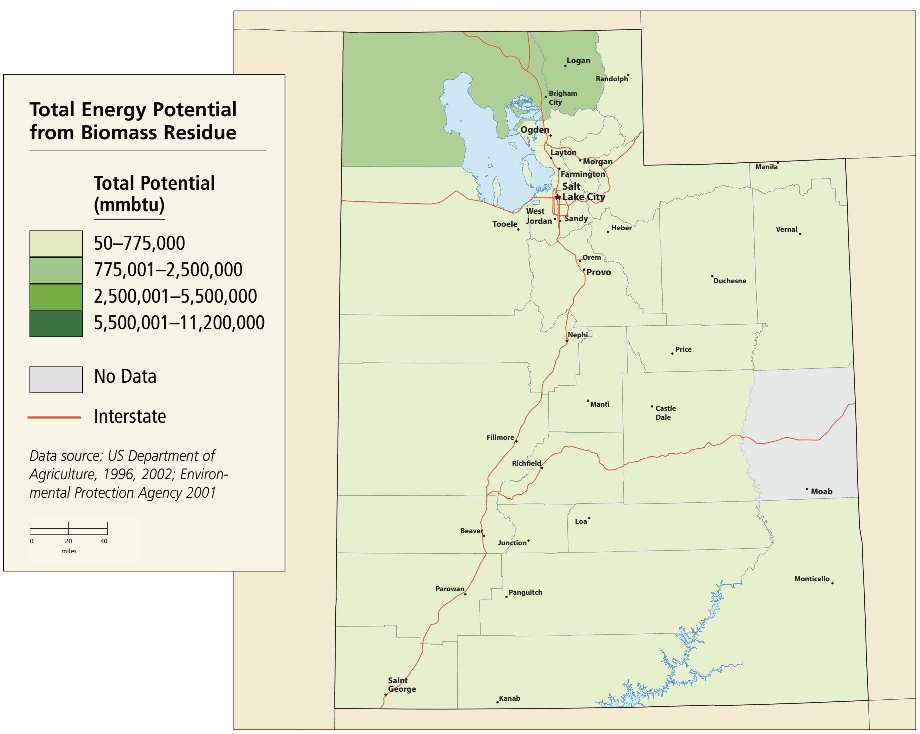
Wind



Areas of Utah contain excellent wind resources that are potentially suitable for utility-scale developments. Utah's largest utility, Utah Power (a subsidiary of PacifiCorp), currently offers customers a wind power option through its Blue Sky program. Although the wind is currently purchased from Wyoming, the state has the potential to generate significant amounts within its own borders. Utah is currently estimated to have 365,000 acres of windy land.

Electricity Generation Potential:
23 million MWh/yr.

Biomass

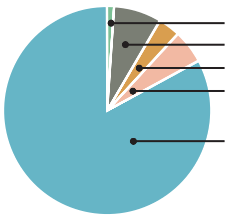


Generating electricity from landfill gas and animal wastes is one avenue for developing bioenergy resources in Utah.

Electricity Generation Potential:
1 million MWh/yr.

Washington Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

Washington ranks second in the region for installed capacity of renewable energy (after California). Commercial wind and biomass developments have achieved initial success in the state, and opportunities abound for additional renewable projects, large and small, to follow.

Renewable Energy Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	178.2 MW
Solar (PV)	0.13 MW
Solar (Thermal)	0.05 MW
Geothermal	0 MW
Biomass	333.3 MW
Total	**512 MW**

[1]Source: REPIS database, plus known installations

Renewable Energy Policies

NM Net Metering
Maximum capacity – 25 kW

GP Green Power Programs
Mandatory utility green power option

$S Sales Tax Exemption

$ Rebate, Grant or Loan Program

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

99 million MWh

Wood Wastes to Electricity

Kettle Falls Wood-Fired Plant

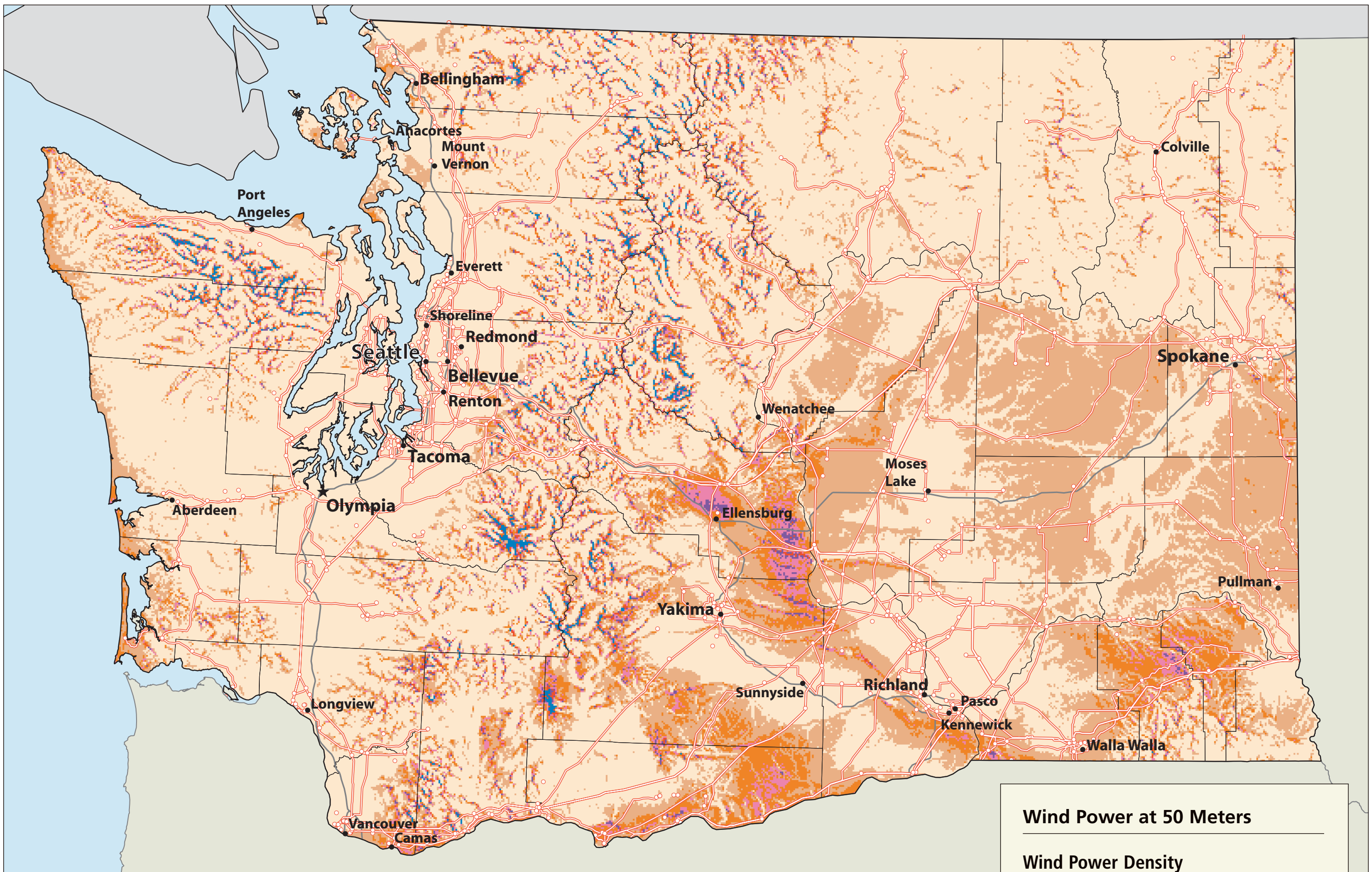
Photo: George Perks, Washington Power

The Kettle Falls wood-fired power plant in Kettle Falls benefits the local lumber industry as well as the environment. The 42.5 MW plant is powered by wood residues that might otherwise be disposed of or burned (without pollution controls) from lumber mills within a 100-mile radius of the plant. Before the plant was built, lumber mills burned their wood waste without pollution controls, contributing to serious air quality problems. The plant, which became operational in 1983, employs a complex system of ash recovery in order to drastically reduce the emissions of particulate matter. The recovered ash is subsequently disposed of in a dedicated solid-waste landfill or marketed as a liming agent. The amount of ash not recovered is well below the state threshold. Electricity generated at Kettle Falls is bought by the Washington Water Power Company, an investor-owned utility serving customers in eastern Washington and northern Idaho.

Wind

Farmers and wind developers alike reap the benefits of "farming the wind" for profit. Four commercial wind farms are producing clean energy in Washington state, while efforts are underway to install additional wind farms and create locally-owned wind cooperatives. Washington has an excellent wind resource, with over 1 million acres of windy land.

Electricity Generation Potential: 62 million MWh/yr.

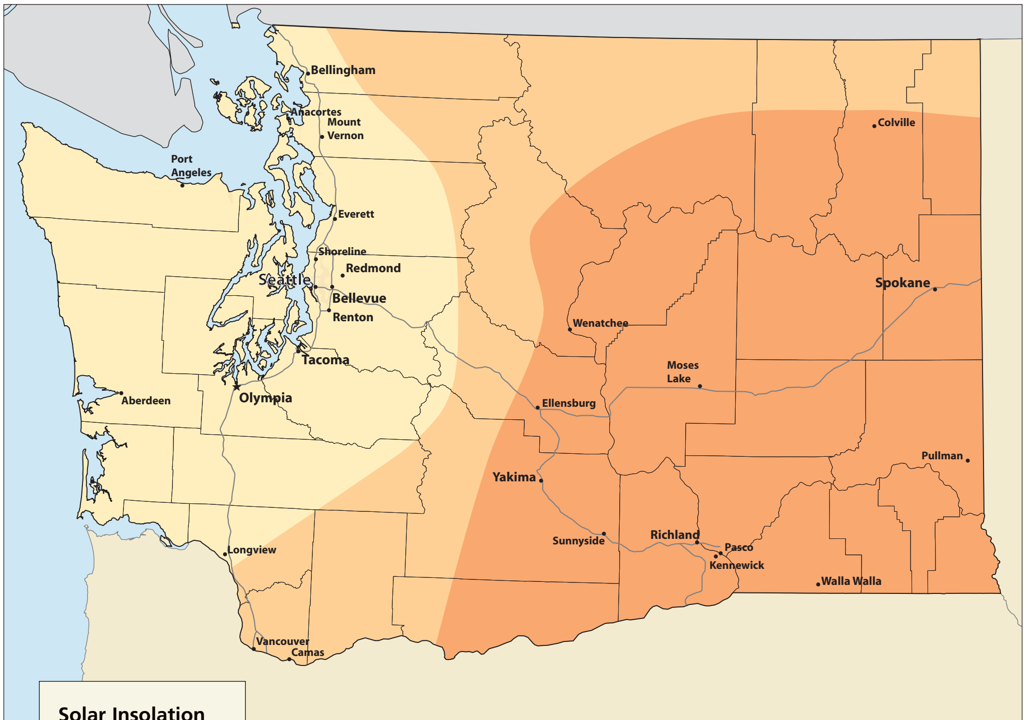


Stateline Energy Center

Rising above the Columbia River along the border of Oregon and Washington, the Stateline Energy Center is the largest individually-owned wind farm West of the Rockies. With a capacity of 263 MW, the project generates enough power to supply more than 70,000 households with emission-free electricity.

Photo: Tim Hall, Capture Photography & Image Solutions

Solar



Despite frequent cloud cover in western Washington through much of the year, the sun is powerful enough to provide home and business owners with enough energy to produce heat and electricity from solar systems.

Electricity Generation Potential:

42 million MWh/yr.

Solar Panels, Westsound Marina

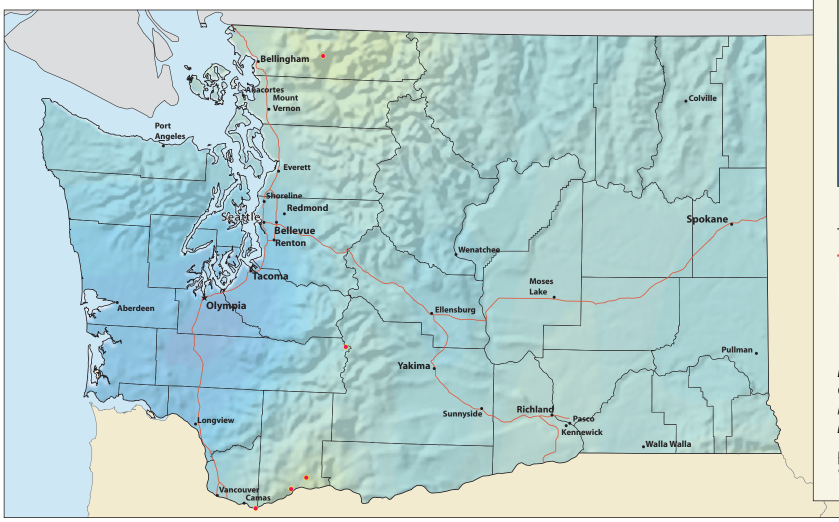
The Green Power program of Orcas Power and Light Cooperative was enhanced in 2001 with the installation of this PV system, in the Westsound Marina, and three others in the San Juan Islands. Funded in part by a $37,000 grant from the Bonneville Environmental Foundation, the four projects will contribute approximately 5,200 kWh annually to the electricity grid.

Photo: Angus Duncan

Geothermal

Home to high volcanic activity, the Cascade Mountain Range in central Washington may provide limited opportunities for direct-use applications.

Electricity Generation Potential: 0 million MWh/yr.

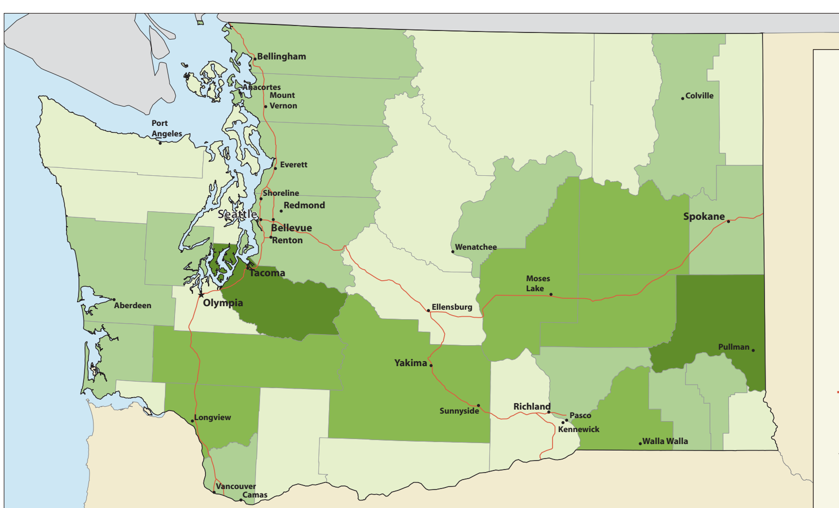


Data source: Western United States Geothermal Database, Southern Methodist University Geothermal Lab 2001

Biomass

Wood wastes from the timber industry and methane gas from landfills are common sources of biomass currently used in Washington. Agricultural crop residues, such as wheat and barley residues, are a biomass source that has not yet been tapped.

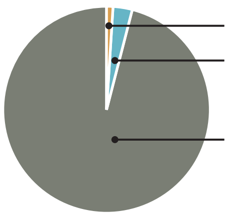
Electricity Generation Potential: 11 million MWh/yr.



Data source: US Department of Agriculture, 1996, 2002; Environmental Protection Agency 2001

Wyoming Renewable Energy Resources

Existing Generation Mix



Data source: Energy Information Administration 1999

Wyoming has one of the best wind resources in the country and is already a large exporter of wind power to Colorado, Oregon and Utah. Wyoming also has good solar and biomass resources. Despite the presence of these renewable resources, however, Wyoming's electricity generation remains dominated by non-renewable resources.

Renewable Energy Installed Renewable Capacity[1]

Resource Type	Installed Capacity
Wind	140.64 MW
Solar (PV)	0.05 MW
Solar (Thermal)	0 MW
Geothermal	0 MW
Biomass	0 MW
Total	**141 MW**

[1]Source: REPIS database, plus known installations

Renewable Energy Policies

NM Net Metering
Maximum capacity – 50 kW

GP Green Power Programs

Data source: Database of State Incentives for Renewable Energy (www.dsireusa.org)

Annual Electricity Consumption (1999)

12 million MWh

Economic Development at Foote Creek Rim

Foote Creek Rim Wind Farm

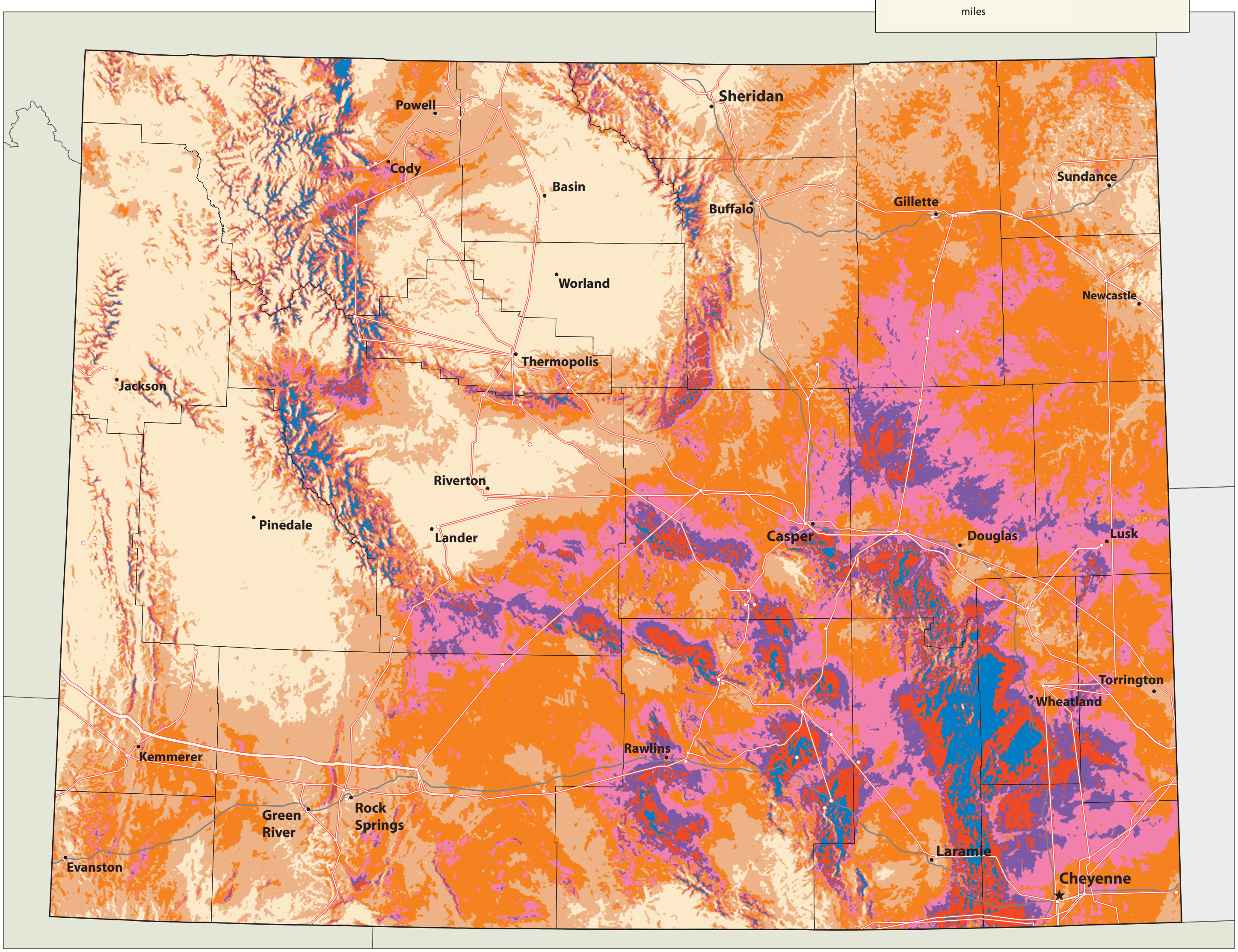
Photo: Tom Hall, DOE

Developing large-scale wind farms not only harnesses the vast potential energy found in the wind but also provides economic benefits for local landowners and residents. The Foote Creek Rim Wind Farm began operations in 1999 and has since grown to include 133 large-scale wind turbines, with a rated capacity of nearly 85 MW. Foote Creek Rim, the first commercial wind farm to go on line in Wyoming, is built on one of the windiest sites in the country. The facility was developed by SeaWest WindPower Inc. in three separate phases, and produces power for PacifiCorp, Eugene (OR) Water and Electric Board, the Bonneville Power Administration and Xcel Energy. Located in Carbon County, Wyoming (population 16,000), the wind farm is a significant contributor to the local economy. This facility will contribute over $9 million in property taxes, nearly $4 million in sales taxes and over $5 million in royalty payments to landowners over its 20-year life span.

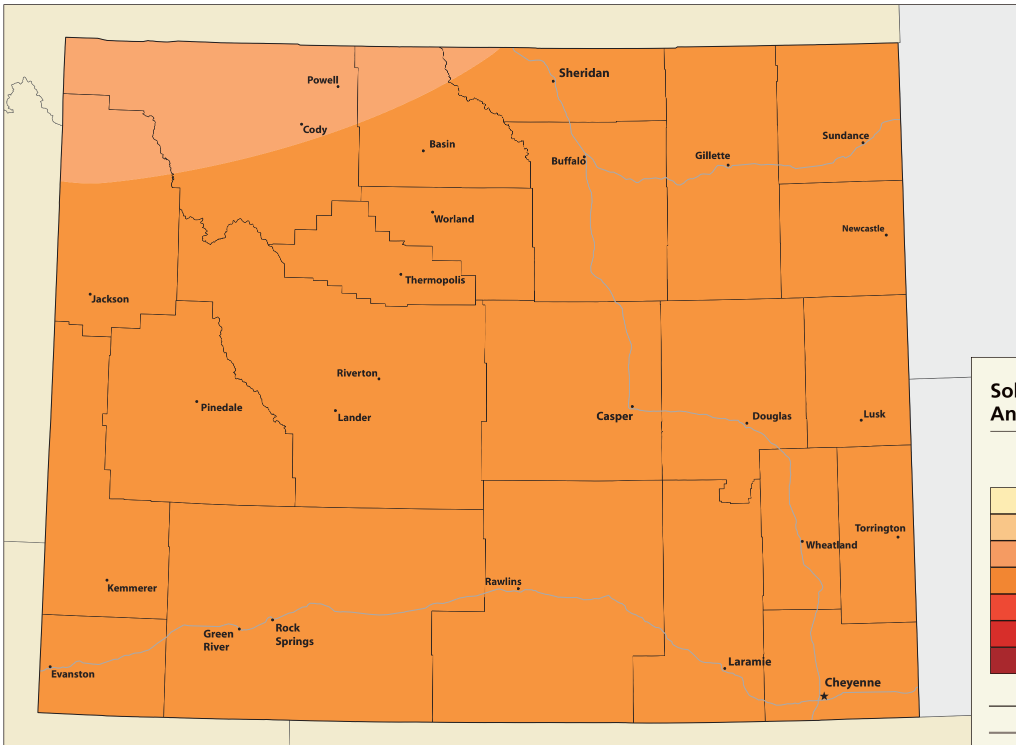
Wind

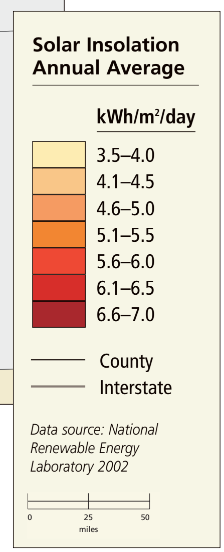
Wyoming has long been recognized for its outstanding wind resource and has already attracted the attention of several wind energy companies that have successfully developed projects in the state. The state is estimated to have over 14 million acres of windy land. Many utilities throughout the Western US buy their "green power" from Wyoming to meet their customers' demand for a cleaner energy portfolio.

Electricity Generation Potential: 883 million MWh/yr.



Solar





Wyoming's solar resource is strong statewide. This clean, renewable energy source can be harnessed through active and passive solar applications.

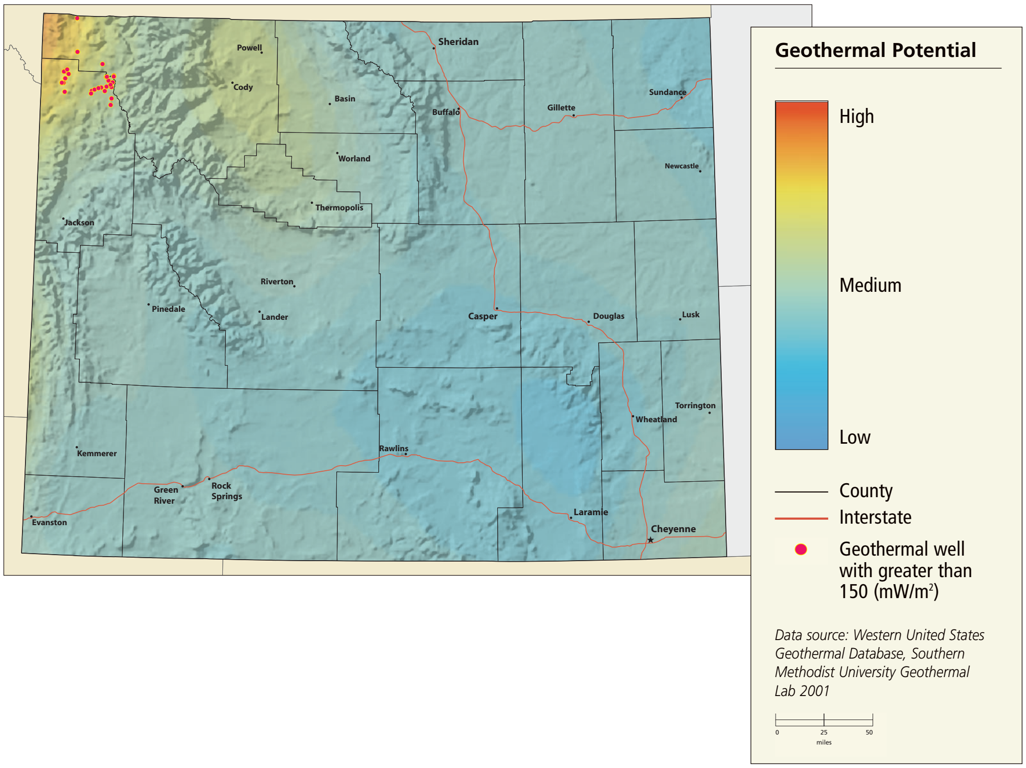
Electricity Generation Potential:
72 million MWh/yr.

Farmer Using Photovoltaics

In parts of rural Wyoming, solar-powered control mechanisms can be used for irrigation systems, such as this PV-powered switch.

Photo: Siemens Solar Industries

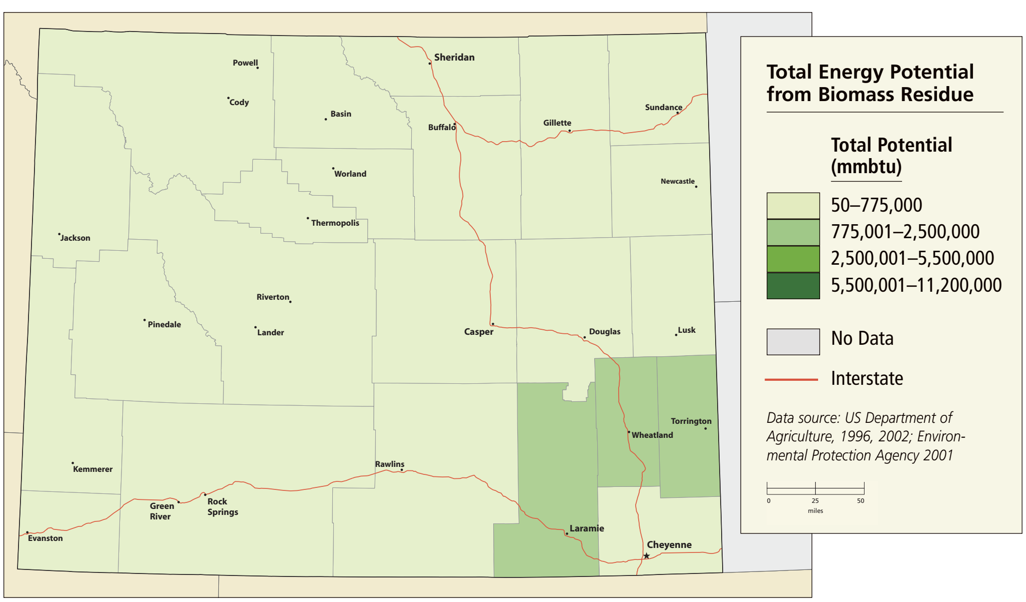
Geothermal



Wyoming's geothermal resources are concentrated in the northwest corner of the state, site of some of America's most famous natural wonders: the geysers and hot springs of Yellowstone National Park. High-temperature geothermal hotspots outside of sensitive environmental areas could prove suitable for electricity generation, while direct heating and cooling may be viable across the state.

Electricity Generation Potential:
N/A

Biomass



There are currently no electricity-producing biomass facilities in Wyoming, although there is limited potential to harness biomass resources in the state.

Electricity Generation Potential:
0 million MWh/yr.

Glossary

Active solar production – using the sun's energy to produce electricity (see Photovoltaics).

Anemometer – an instrument used to measure wind speed.

Biomass (also referred to as bioenergy) – the process of converting forestry and agricultural crops, crop processing wastes and residues, animal manures, and landfill methane gas into electricity or thermal energy in processing plants.

BTU (British Thermal Unit) – a measure of the heat content of a substance that is burned to produce energy; equivalent to the burning of one match stick.

Capacity factor – the value of the average power output of a generating system compared to the capacity rating of the system over a specified period of time.

Co-firing – using more than one fuel source to produce electricity in a power plant. Common combinations include biomass and coal, biomass and natural gas, or natural gas and coal.

Concentrating solar power – technologies that capture solar energy by converting the sun's light into heat by concentrating direct radiation onto a receiver, where it is absorbed into a fluid. The heat in the fluid is transported to a heat engine that converts the thermal energy into electricity.

District heating system – local system that provides thermal energy through steam or hot water piped to buildings within a specific geographic area. Used for space heating, water heating, cooling, and industrial processes. A common application of geothermal resources.

Distributed generation – small power plants sited at many locations, which can be used to reduce burden on a transmission system by generating electricity close to areas of customer need, thereby reducing the need for transmitting electricity during peak times.

Energy crop – a plant grown with the express purpose to be used in biomass electricity or thermal generation.

Geothermal – heat, in the form of hot water, steam, or rocks, near the surface of the earth's crust used for direct heating and cooling, or for electricity generation.

Geothermal heat pump – device which circulates geothermally heated fluid through sealed pipes to transfer heat from one area to another to cool or heat an interior space.

Installed capacity – amount of power that could be generated by an energy source if operated at its maximum capacity. Expressed in wattage, usually kilowatts (kW) or Megawatts (MW).

kW (kilowatt) – 1000 watts (see W).

kWh (kilowatt-hour) – unit of energy equivalent to one kilowatt (kW) of power expended for one hour of time; common measurement of electricity.

Landfill gas – naturally occurring methane produced in landfills; can be burned in a gas turbine to produce electricity.

Large-scale – *see Utility-scale.*

Load – amount of electricity required to meet customer demand at any given time.

Load growth – increase in the amount of consumer demand for electricity

MW (Megawatt) – 1,000,000 watts, or 1,000 kilowatts.

MWh (Megawatt-hour) – 1,000 kWh.

Passive solar design – construction of a building to maximize solar heat gain in the winter and minimize it in the summer, thereby reducing the use of mechanical heating and cooling systems.

Peak load – the amount of electricity required to meet customer demand at its highest.

Photovoltaics (PV) – devices that convert sunlight directly into electricity using semiconductor materials. Most commonly found on a fixed or movable panel; also called solar panels.

Policy Definitions –

Green Power Program – an option offered to customers by a utility to pay a premium for a "green" power source (frequently wind or solar). Usually designed to support the development of new renewable energy facilities above regulatory requirements.

Net Metering – policy allowing customers with their own generating units to sell excess power back to the grid, enabling the flow of electricity to and from the customer through a single, bi-directional meter. Net metering laws typically include a limit on the size of generating units, ranging from 1 kW to more than 1,000 kW. Some utilities require use of dual meters and sale of power to the utility at avoided energy costs, termed "net billing."

"Other" – rebates, loans or grant programs offered by the state or a utility to assist in financing renewable energy projects.

Property tax exemption – an exemption, exclusion or credit against property taxes.

Renewable Portfolio Standard – a requirement that a certain percentage of a utility's overall capacity of electricity sales be derived from renewable resources.

Sales tax exemption – an exemption from state sales tax for the cost of renewable energy equipment.

System Benefits Charge – fee implemented to assure financial support for renewable energy, energy efficiency and/or low-income support programs. Typically a small charge to all customers on the basis of electricity consumption.

Tax incentives (personal/corporate) – income tax credits or deductions for the purchase and/or installation of renewable energy equipment.

Power production potential – amount of electricity that could be generated from an energy resource.

Small-scale or residential-scale – a generating facility designed to output enough electricity to offset the needs of a residence, farm or small group of farms; generally 250 kW or smaller.

Solar easement – right expressed as an easement, restriction, covenant or condition obtained by the landowner for the purpose of exposure of an active or passive solar energy system to the direct rays of the sun.

Renewable resource – energy sources which are continuously replenished by natural processes: wind, solar, biomass and geothermal.

Transmission grid – the network of power lines and associated equipment required to deliver electricity from generating facilities to consumers.

Transmission constraints – areas within the transmission system where problems with delivering electricity from generator to customer develop, including power lines with too little capacity for the amount of electricity to be moved.

Utility-scale (commercial-scale) – a power generating facility designed to output enough electricity for purchase by a utility.

W (watt) – instantaneous measure of power, equivalent to just less than one thousandth of a horse power and just over three thousandths of a BTU.

Watts per square meter of the blade swept area – unit used to measure wind power density.

Wind power – measured in watts per square meter.

Wind speed – measured in meters per second.

Data Sources and Methodologies

Wind

Wind Maps – Data Sources

Arizona, California, Nevada and Utah – Wind Energy Resource Atlas of the United States, Pacific Northwest Laboratory (PNL), 1987.

Colorado – Brower and Company for Colorado Office of Energy Conservation, 1995.

New Mexico – Brower and Company for New Mexico Department of Energy, Minerals and Natural Resources, 1997.

Idaho, Montana, Oregon, Washington, Wyoming – TrueWind Solutions High-Resolution Wind Mapping Project for Northwest SEED, 2002.

Wind Generation Potential Estimates

Wind resource maps for the eleven Western states are currently available in varying degrees of accuracy and resolution. These estimates were developed using the most recent figures available for each state (sources given above).

Idaho, Montana, Oregon, Washington and Wyoming

The wind data were generated by TrueWind Solutions using their MesoMap wind mapping system. This system combines a numerical weather model and a microscale wind flow model to produce a high-resolution wind resource map that accounts for complex flows, such as channeling, sea breezes, downslope winds, and other effects. These high-resolution data were fully validated by NREL.

Land Use Exclusions

The exclusion criteria were developed in coordination with NWSeed and NREL. Although NREL is still in discussions with the Department of Energy, and has not finalized their definitions of exclusion zones, these guidelines represent their current thinking. The areas 100% excluded fall under three general categories:

1. Landforms – land with a slope of greater than 20%
2. Environmentally sensitive areas
    a. All National Park Service lands
    b. All Fish and Wildlife lands
    c. All Forest Service or BLM lands with a "special" designation, such as National Recreation Area or National Wilderness Area
3. Land use exclusions
    a. All bodies of water
    b. Wetlands
    c. Urban areas

Other land use exclusions were not applied because development will depend on conditions in individual project areas.

Colorado and New Mexico

These maps were developed by Brower and Company, in collaboration with consulting meteorologist Richard L. Simon, using GIS-based regression models. The 1987 US Wind Atlas was the starting point for the CO map; modifications in the wind resource estimates were made to account for the effects of local terrain exposure and roughness as well as new wind data that had become available, particularly in mountainous areas. The NM map was developed independently of the 1987 US Wind Atlas using data from nearly 70 towers located throughout the state. The maps have not been independently validated. No attempt was made to reconcile the two maps at the borders. In addition, the CO map was based on wind power, whereas the NM map was based on wind speed and subsequently converted. For these reasons there is a noticeable discontinuity at the border between the two maps. New maps for both states, will be produced by TrueWind Solutions and are scheduled for completion in early 2003.

Land Use Exclusions were the same as above.

Arizona, California, Nevada and Utah

The analysis for Arizona, Nevada, California and Utah relied on tabular data produced by PNL in 1991 and 1992. The 1992 report provides the most accurate calculations for windy land area by state, with varying definitions of exclusions presented. However, it did not provide a breakdown of windy land area by wind class. In order to provide this level of detail, the total windy land area in the 1992 report was interpolated down to wind classes, based on the percentages for each category represented in the 1991 report. Prior to 1995, when Brower produced the map of Colorado, no GIS compliant data had been created to accurately model wind resources in the Western United States. The maps contained in the 1987 Atlas presented a coarse wind resource assessment by assigning a single wind power class to each 25km^2 grid cell. The power class assigned to the cell represents the maximum wind power class likely to occur on well-exposed areas within that grid cell. To account for the variation in terrain, each grid cell was assigned a terrain exposure factor varying from 5% (representing exposed ridgecrests) to 95% (flat open plains).

Land Use Exclusions

Since GIS compliant data were not available at the time the 1991 and 1992 data were created, exclusions were based on manually tabulated data. First, all federal and state environmentally sensitive lands were 100% excluded from development. These lands included parks, monuments, US Forest Service lands, wilderness areas and wildlife refuges. The available windy land area was further reduced by exclusions based on the primary land use of each region. Percentages were determined for eight land use types:

1. Forest – 50% excluded
2. Agriculture – 30% excluded
3. Range – 10% excluded
4. Mixed Agriculture and Range – 20% excluded
5. Barren – 10% excluded
6. Wetland – 100% excluded
7. Urban – 100% excluded
8. Water – 100% excluded

Because of the change in exclusion methodologies, the 2002 Wind Area figures reflect more of a gross potential than these 1992 numbers. This difference in emphasis accounts for much of the contrast between the 1992 and 2002 Wind Area figures land area for the individual states.

Sources:

"An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States," 1991, Pacific Northwest Laboratory (PNL), by Dennis Elliott, Larry Wendell and Gene Gower.

"Gridded State Maps of Wind Electric Potential," 1992, by Marc Schwartz, Dennis Elliott and Gene Gower, presented at Windpower 1992.

Solar

Solar Maps – Data Sources

National Renewable Energy Laboratory, 2002

George, R., and E. Maxwell, 1999: "High-Resolution Maps of Solar Collector Performance Using Climatological Solar Radiation Model," Proceedings of the 1999 Annual Conference, American Solar Energy Society, Portland, ME.

Maxwell, E., R. George and S. Wilcox: "A Climatological Solar Radiation Model," Proceedings of the 1998 Annual Conference, American Solar Energy Society, Albuquerque, NM.

Marion, W. and S. Wilcox, 1994: "Solar Radiation Data Manual for Flat-plate and Concentrating Collectors." NREL/TP-463-5607, National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, CO 80401.

Details: This map provides annual average daily total solar resource information on grid cells of approximately 40 km by 40 km in size. The insolation values represent the resource available to a flat plate collector, such as a photovoltaic panel, oriented due south at an angle from horizontal equal to the latitude of the collector location. This is typical practice for PV system installation, although other orientations are also used.

The map was developed with data derived from the Climatological Solar Radiation (CSR) model. The CSR model was developed by the National Renewable Energy Laboratory for the US Department of Energy. Specific information about this model can be found in Maxwell, George and Wilcox (1998) and George and Maxwell (1999). This model uses information on cloud cover, atmospheric water vapor and trace gases, and the amount of aerosols in the atmosphere, to calculate the monthly average daily total insolation (sun and sky) falling on a horizontal surface. The cloud cover data used as input to the CSR model are an 8-year histogram (1985–1992) of monthly average cloud fraction provided for grid cells of approximately 40 km x 40 km in size. Thus, the spatial resolution of the CSR model output is defined by this database. The data are obtained from the National Climatic Data Center in Asheville, North Carolina, and were developed from the US Air Force Real Time Nephanalysis (RTNEPH) program. Atmospheric water vapor, trace gases, and aerosols are derived from a variety of sources, as summarized in the references. The procedures for converting the modeled global horizontal insolation into the insolation received by a flat plate collector at latitude tilt are described in Marion and Wilcox (1994).

Where possible, existing ground measurement stations are used to validate the model. Nevertheless, there is uncertainty associated with the meteorological input to the model, since some of the input parameters are not available at a 40 km resolution. As a result, it is believed that the modeled values are accurate to approximately 10% of a true measured value within the grid cell. Due to terrain effects and other microclimate influences, the local cloud cover can vary significantly even within a single grid cell. Furthermore, the uncertainty of the modeled estimates increases with distance from reliable measurement sources and with the complexity of the terrain.

After acquisition from NREL, GreenInfo Network smoothed the data by interpolating a grid using the centroids of the 40 km cells as data points using a inverse distance weighted function. The annual average of the daily solar radiation were used, as described above. The raster resolution of the interpolated grid was 3 km. These data were then smoothed using an averaging filter to simplify data and improve map legibility.

Solar Generation Potential Estimates

These estimates represent a possible scenario of the energy that could be generated from distributed solar photovoltaic installations, as opposed to centralized power stations, based on simple assumptions limiting their maximum deployment:

1. Solar power producing systems can be installed on rooftops and open spaces representing 0.5% of the total area of each state.
2. Solar panels will occupy 30% of the area set aside for solar equipment, with the balance taken up by support structures, access paths and other equipment.

3. Solar energy can be converted to electricity at an average system efficiency of 10%. Although crystalline silicon photovoltaic modules have demonstrated efficiencies as high as 22.7% under laboratory conditions, commercially viable systems average much lower, particularly when total system efficiencies are considered. In addition, heat can have a major impact on panel efficiencies in a real world setting, typically leading to a derating of 10% or more in sunny environments. Reliance on other forms of solar electrical production, using concentrating photovoltaic collectors or solar thermal systems, would introduce a very different set of assumptions and results.

The results represent theoretical potentials, moderated by these simple constraints, and do not take economic realities into account. Market conditions, local environmental considerations, and future developments in solar technologies and other energy sources will ultimately determine the economic viability of solar penetration at these levels.

Geothermal

Geothermal Maps – Data Sources

Southern Methodist University Geothermal Lab, 2001
http://www2.smu.edu/geothermal/georesou/resource.htm

Details: The data used to produce the geothermal maps are derived from a model that incorporates heat flow, thermal gradient, sediment thickness, hot springs and previous maps by the DOE and EGI-UURI. The well locations on the map are taken from the Western US Geothermal database and represent those records with an uncorrected heat flow gradient greater than 150 mW/m^2 at the deepest interval sampled. This was suggested by scientists at SMU as an approximate cut-off for sites with a gradient suitable for electricity production. It should be noted that several factors determine the suitability of an area for geothermal electricity production and that site-specific tests would be needed before developing the resource potential.

The values in the composite model used are unit-less; they do not represent actual heat flow. The actual data were received from SMU as a text file and were converted to an ArcView shapefile of points for the Western US. These points were interpolated using an inverse distance weighted method at a cell size of 3 km. The data values were divided into 30 equal intervals and were assigned colors. These data were then draped onto a hillshade of terrain for the region at 1 km resolution.

Geothermal Generation Potential Estimates

These figures were taken from the Geothermal Electric Submodule of the Renewable Fuels Module of the National Energy Modeling System (NEMS). Details on the model are available at:
http://tonto.eia.doe.gov/FTPROOT/modeldoc/m069(2002).pdf

The estimates given on page 13 include geothermal resources which would produce electricity at less than $60 per MWh.

Biomass

Biomass Maps – Data Sources

Landfill Gas: Landfill Methane Outreach Program (LMOP) database (2001)
http://www.epa.gov/lmop/projects/projects.htm

Crop residues: USDA Published Estimates Database (PEDB) (2000–2001)
http://www.nass.usda.gov:81/ipedb/ for corn, wheat and barley

Forest Residue: USDA Forest Service's Forest Inventory and Analysis Database (FIADB) (1996)
http://www.fia.fs.fed.us/

Animal Waste: USDA Published Estimates Database (PEDB) (2000–2001).
http://www.nass.usda.gov:81/ipedb/ for dairy cattle, beef cattle, swine and sheep

Biomass Generation Potential Estimates

Landfill Gas

Landfill gas resources were estimated by aggregating the MW capacities of both existing landfill gas recovery systems and potential future systems, as estimated by EPA in their Landfill Methane Outreach Program database (2001).

For some of the landfills identified in the EPA database no capacity estimates are specified. For these landfills, EPA does provide estimates for total waste material buried in the landfill (in tons). In order to estimate likely system capacities, a regression of the natural logarithm of generation capacity was fitted on tons of buried waste at existing and potential sites where both capacity and buried tons are documented.

$$\ln(MW) \sim tons$$

where:

- MW is the generation capacity of the landfill.
- $tons$ is the number of tons of garbage contained in the landfill.

This log linear regression has an R^2 value of approximately 0.3. The regression yields the following equation for electric capacity in MW:

$$MW = e^{((6.40 \times 10^{-8})\, tons + 0.383)}$$

This formula was used to estimate generation capacity where only tonnage values are available. 29% of the landfill capacity estimates were calculated using this formula. Where multiple projects exist at one landfill, estimates were adjusted so that the sum of estimated project generation capacities does not exceed the total estimated capacity for the landfill. Annual expected production was calculated by multiplying the capacity (MW) by 8760 hrs/yr. The conversion from heat energy to electrical energy is assumed to be 25% efficient. When calculating annual heat energy, an energy transfer factor of 13,600 kWh/BTUs was used which incorporates the assumed efficiency.

Crop Residues

The principal grains – corn, wheat, and barley – are the major source of potentially usable crop residues in the West. Crop residue resources were calculated using data acquired from the USDA Published Estimates Database (2000–2001). Annual expected generation due to crop residues was calculated using:

$$\frac{bushels \times lb\_per\_bushels \times residue\_fraction \times energy\_density \times residue\_factor \times moisture\_factor}{2000 \times energy\_transfer\_factor \times 1000} = MWh$$

where:

- $bushels$ is bushels of grain harvested (USDA data)
- lb_per_bushel is the weight of an average bushel. The assumed weight per bushel of each grain follows:
  – barley 48 lb/bushel
  – corn 56 lb/bushel
  – wheat 60 lb/bushel
- $residue\_fraction$ is the assumed fraction of residue that can be taken from fields after harvest without negatively affecting soil quality. A residue fraction of 0.30 was used for all grains.
- $energy\_density$ is the energy contained in 1 ton of residue. Each ton of residue is assumed to contain 15.0×10^6 BTUs [Kerstetter and Lyons, 2001]

- *residue_factor* is used to determine the amount of available residue based on the grain harvest. The residue factors used for each grain follow:
  – barley 1.50
  – corn 1.00
  – winter wheat 1.70
  – durum wheat, spring wheat 1.30
- *moisture_factor* is used to adjust the weight of the residue to a dry weight. The moisture factors used for each grain follow:
  – barley 0.90
  – corn 1.00
  – winter wheat 0.87
  – durum wheat, spring wheat 0.87
- *energy_transfer_factor* is a conversion factor used to convert between electrical energy and heat energy. Assuming a 25% efficient boiler, the energy transfer factor is 13,600 kWh/BTU.

Forest Waste

Forest waste resources are based on an aggregation of forest waste and mill waste annual energy capacity data from the USDA Forest Service's Forest Inventory and Analysis Database (1996). Urban waste (municipal solid waste) is not included. The conversion from heat energy to electrical energy is assumed to be 25% efficient. When calculating annual heat energy, an energy transfer factor of 13,600 kWh/BTUs was used which incorporates the assumed efficiency.

Animal Waste

Animal waste resources were estimated by combining county totals of dairy cattle, beef cattle, swine and sheep. Estimated county totals were acquired from the USDA Published Estimates Database (2000–2001). Annual expected generation due to animal waste was calculated using:

$$\frac{365 \text{x} \, animals \, \text{x} \, volatile\_solids \, \text{x} \, volume \, \text{x} \, energy\_per\_volume \, \text{x} \, (1 - handling\_loss) \, \text{x} \, digester\_efficiency}{1000 \, \text{x} \, energy\_transfer\_factor} = MWh$$

where:

- *animals* is the number of animals.
- *volatile_solids* is the weight in lbs of volatile solids produced by a typical animal each day. Volatile solids assumed for each animal follow:
  – beef cattle 6.00 lb/animal/day
  – dairy cattle 11.20 lb/animal/day
  – swine 1.20 lb/animal/day
  – sheep 0.92 lb/animal/day
- *volume* is the volume in ft^3 of gas generated from each lb of volatile solids. Volumes for each animal follow:
  – beef cattle: 9.76 ft^3/lb
  – dairy cattle, sheep 14.00 ft^3/lb
  – swine 8.00 ft^3/lb
- *energy_per_volume* is the energy in BTU's contained in each ft^3 of gas. Energy per volume of each animal follows:
  – beef cattle, dairy cattle, sheep 600 BTU/ft^3
  – swine 650 BTU/ft^3

- *handling_loss* is the expected waste management handling loss. Expected waste management handling losses for each animal follow:
  – beef cattle, sheep 0.25
  – dairy cattle 0.10
  – swine 0.20
- *digester_efficiency.* Expected digester efficiencies for each animal follow:
  – beef cattle, swine 0.50
  – dairy cattle, sheep 0.35
- *energy_transfer_factor* is a conversion factor used to convert between heat energy and electrical energy. Assuming an internal combustion engine efficiency of 25%, the energy transfer factor is 13,600 kWh/BTU.
- 365 days equals one year. This is used to convert daily generation to annual expected generation.

Electricity Generation (p. 16):

Data source: Energy Information Administration, Electric Power Annual 2000, Volume I – Net Generation of Industry by state and resource for year 1999

Renewable Energy Facilities (p. 18):

Installed Capacity and Location Data source: REPiS: The Renewable Electric Plant Information System, 2001; American Wind Energy Association, 2002

The REPiS database records information on the status, capacity and fuel types of renewable energy facilities producing electricity with some information on the geographic location of the facilities. The location of most of the records can be derived from the city or name or the zip code. Only operating plants at the time of the release of the data were included in the mapping. Because the American Wind Energy Association data were more current, (for wind facilities) we used this for capacity and location for records that did not appear in the REPiS database.

In locating the facilities to map within a GIS, we used the most accurate geographic reference feature available for that record. For example, if the zip code was available for the plant we used that to link to the GIS, then city names, then county names. Within the GIS, cities were represented as points and counties and zip codes as polygons. For the polygon features, we used the centroid of the shape as the location of the plant. More than one facility may be represented by the icon on the map because we had to aggregate all records with same geographic locator. Out of 1,768 records for all facilities, 314 did not have either zip codes, counties or cities and could not be located using the GIS. Some of the records that did have a record for zip code, city or county name could not be located because of various reasons, often a missing zip code in the GIS data or a different spelling. These were not significant for any fuel or geography except for the city–solar combination. Out of 387 cities in the REPiS database with an operation solar facility, 85 were not matched. This was likely due to misspellings, unincorporated cities that may not appear in the GIS data, or use of local place names that would not be in the GIS data. This affects only the location map and not the installed capacity totals as these were compiled directly from the REPiS data.

Renewable Energy Policies (p. 19)

Data source: Database of State Incentives for Renewable Energy (DSIRE), updated June 2002, www.dsireusa.org

The West at Night (p. 20)

Data source: National Geophysical Data Center 2000

This image of the Lights of North America was downloaded from www.nationalatlas.gov. Transmission lines are shown courtesy of Platts, POWERmap, powermap.platts.com ©2002 Platts, A Division of The McGraw-Hill Companies.

Load Growth (p. 21)

Data source: *A Conceptual Plan for Electricity Transmission in the West, a Report to the Western Governors' Association,* August 2001, Figure 7, page 23

Transmission Constraints (p. 22)

Data source: *A Conceptual Plan for Electricity Transmission in the West, a Report to the Western Governors' Association,* August 2001, Figure 6, page 22; POWERmap, powermap.platts.com ©2002 Platts, A Division of The McGraw-Hill Companies

Land Use Considerations (p. 23)

Data source: National Atlas of the United States, USGS 1999; Bureau of Land Management 1999, Arizona Land Resource Information System, Colorado Department of Transportation 2001, Idaho Gap Analysis Project 1999, Montana Natural Heritage Program 2002, Nevada Gap Analysis Project 1996, New Mexico Gap Analysis Project 1996, Oregon State Service Center 1993, Utah Gap Analysis Project 1995, Wyoming Gap Analysis Project 1996

Environmental Impacts of Fossil Fuels (p. 24)

Data source: EPA Acid Rain Program (Title IV) Emissions Scorecard, 2000

Details: The annual values for SO_2, NO_X and CO_2 for the eleven Western states were selected from the full data set. The corresponding GIS data of plant locations was downloaded from the Clean Air Mapping and Analysis Program Web site (www.epa.gov/airmarkets/cmap/index.html) and was used to tie the emissions data to the plant location. These point locations of plants were buffered 10 miles to give them an areal extent necessary for the 3D visualization. Using ArcView 3D analyst, we created the images by scaling the height of the bars (centered on plant locations) to the emissions in 2000. SO_2 and NO_X were scaled proportionally by multiplying the emissions (tons) by 5 to derive the height of the bars. Because CO_2 emissions are so much higher (in terms of tons), a different scaling factor was applied. The amount of CO_2 emitted was divided by 40 to derive the height of the bars.

For More Information

US Department of Energy

http://www.energy.gov
The US Department of Energy's home page provides information on federal programs relating to energy.

National Renewable Energy Laboratory

http://www.nrel.gov
The US Department of Energy's premier laboratory for renewable energy research & development.

Wind

Wind Powering America

http://www.eren.doe.gov/windpoweringamerica/
The US Department of Energy's program to dramatically increase the use of wind power across the country.

National Wind Technology Center

http://www.nrel.gov/wind/
The US Department of Energy's wind power research facility.

American Wind Energy Association

http://www.awea.org
A national trade association promoting the development of wind power.

Solar

DOE Solar Energy page

http://www.eren.doe.gov/RE/solar.html

American Solar Energy Society

http://www.ases.org
A national association dedicated to advancing the use of solar energy.

Biomass

DOE BioPower Program

http://www.eren.doe.gov/biopower/main.html

American Bioenergy Association

http://www.biomass.org/
A national trade association advancing the use of biomass energy.

Geothermal

DOE Geothermal Energy page

http://www.eren.doe.gov/RE/geothermal.html

Geothermal Resources Council

http://www.geothermal.org
A non-profit organization that provides educational information about geothermal resources.

Policies Supporting Renewable Energy

Database of State Incentives for Renewable Energy
http://www.dsireusa.org
This database provides information on tax incentives, rebate programs, portfolio standards, green power programs and other state-level policies that encourage renewable energy development.

State Energy Offices

Directory of State Energy Offices
http://www.naseo.org/links/states.htm

More links are listed on the Renewable Energy Atlas page: http://www.EnergyAtlas.org.

About the Atlas

For more information about the Atlas contact:

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Contributing organizations:

The Land and Water Fund of the Rockies

The Land and Water Fund of the Rockies uses law, economics, and policy analysis to protect land and water resources, protect essential habitats for plants and animals, and ensure that energy demands are met in environmentally sound and sustainable ways. The Energy Project at the Land and Water Fund develops policies and markets to promote sustainable energy technologies and improve air quality in the Interior West.
www.lawfund.org

Northwest S·E·E·D Sustainable Energy for Economic Development

Northwest Sustainable Energy for Economic Development (NWSEED) works to mobilize consumers and maximize local benefits from harvesting "homegrown" renewable resources – wind, solar, biomass, geothermal, and low-impact hydro coupled with conservation and bio-based products – while fostering self-sufficiency and creating new revenue streams. Through strategic partnerships and collaborative efforts, Northwest SEED supports and develops creative programs, policies and financing approaches to build rural economies and diversify the region's energy supply with affordable, distributed "green" generation.
www.nwseed.org

GreenInfo Network

GreenInfo Network brings the power of mapping, information and communications technology to non-profits, governmental agencies and other public interest organizations, enabling them to more effectively understand and show the relationships between issues, people and places. Their mission is accomplished by: using technology to envision and produce effective, efficient and creative visual and data products for clients; enabling others to use these same tools; educating the public about the importance of place-based thinking in public policy issues; and communicating critical information on key public policy issues.
www.greeninfo.org